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TABLE RONDE NATIONALE SUR L'ENVIRONNEMENT ET L'ÉCONOMIE

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Discussion Paper

SUSTAINABILITY AND PROSPERITY:

THE ROLE OF INFRASTRUCTURE

Prepared for:

The National Round Table on the Environment & the Economy

September, 1992

Daryl Fields
The ARA Consulting Group Inc.
402-475 Howe Street
Vancouver, B.C. V6C 2B3
Tel (604) 681-7577
Fax (604) 669-7390

Jack Ruitenbeek
H.J. Ruitenbeek Resource Consulting
303-116 Albert Street
Ottawa, Ontario K1P 5G3
Tel (613) 235-3824
Fax (613) 238-5394

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Daryl Fields
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Jack Ruitenbeek
H.J. Ruitenbeek Resource Consulting
303-116 Albert Street
Ottawa, Ontario K1P 5G3
Tel (613) 235-3824
Fax (613) 238-5394

SUSTAINABILITY AND PROSPERITY SYMPOSIUM
List of Participants
November 17-18, 1992
Toronto

Mr. Steve Barg (Group A)
Program Manager
International Institute for
Sustainable Development
161 Portage Ave East
Winnipeg, Manitoba
R3B 2L6

Mr. Reg Basken **(Group C)**
President
Energy and Chemical Workers Union
Suite 202
9940 - 106 Street
Edmonton, Alberta
T5K 2N2
(403) 422-7932
(403) 424-2505 fax

Professor Fred Bienefeld
School of Public Administration
Carleton University
Dunton Tower
1125 Colonel By Dr.
10th floor, Room 1021
Ottawa, Ontario
K1S 5B6
(613) 788-2547
(613) 788-2551 fax

Mr. François Bregha **(Group C)**
Director, Policy Studies Program
The Rawson Academy of Aquatic Sciences
1 Nicholas Street, Suite 404
Ottawa, Ontario
K1N 7B7
(613) 563-2636
(613) 563-4758 fax

Mr. Raymond Brouzes **(Group C)**
Managing Environmental Change
540 Bridle Path Road
Hudson Heights, Quebec
J0P 1J0
(514) 458-4637
(514) 458-1543 fax

Mr. Tony Cassils **(Group A)**
211 Wurtemburg Street #2101
Ottawa, Ontario
K1N 8R4
(613) 238-2296
(613) 238-8515 fax

Philippe Clément **(Group B)**
Policy Advisor, Task Force on Tools
NRTEE

Dr. George Connell, Chair
National Round Table
Environmental Assessment Board
Ont. Hydro Demand/Supply Plan Hearing
2200 Yonge St., 5th Floor
Toronto, Ontario
M4S 2C6
(416) 324-7373
(416) 324-7380 fax

Mr. John H. Dales **(Group C)**
232 Rose Pard Drive
Toronto, Ontario
M4T 1R5
(416) 483-5375

Professor Don Dewees **(Group B)**
Office of the Dean
Faculty of Arts and Science
Sidney Smith Building, Room 2020
University of Toronto
Toronto, Ontario
M5S 1A1
(416) 978-4439
(416) 978-3887 fax

Mr. John Dillon **(Group A)**
Business Council on National Issues
90 Sparks Street, Suite 806
Ottawa, Ontario
K1P 5B4
(613) 238-3727
(613) 236-8679 fax

Ron Doering
Executive Director
NRTEE

Dr. John Evans **(Group C)**
Chairman
Allelix Inc.
6850 Joreway Drive
Mississauga, Ontario
L4V 1P1
(416) 677-0831
(416) 677-9595 fax

Ms. Jeanine Ferretti **(Group B)**
Pollution Probe
12 Madison Avenue
Toronto, Ontario
M5R 2S1
(416) 926-1907
(416) 926-1601 fax

Anne Fouillard **(Group C)**
Policy Advisor, Foreign Policy
NRTEE

Mr. Michael Francino **(Group A)**
Acting Assistant Deputy Minister
Economic Development Policy Branch
Finance Canada
140 O'Connor Street, 12th floor
L'Esplanade Laurier
Ottawa, Ontario
K1A 0J5
(613) 992-6403
(613) 992-0387 fax

Mr. Gary Gallon **(Group B)**
Environmental Economics International
9 Sulton Street, Suite 300
Toronto, Ontario
M5S 1L6
(416) 972-7400
(416) 972-6440 fax

Mr. John Godfrey **(Group A)**
Vice President
Canadian Institute for Advanced Research
179 John Street, Suite 701
Toronto, Ontario
M5T 1X4
(416) 971-4251
(416) 971-6169 fax

Mr. J.G. Goodfellow **(Group A)**
Deloitte & Touche
95 Wellington Street West, 14th floor
Toronto, Ontario
M5J 2P4
(416) 601-5650
(416) 601-5921 fax

Mr. Yves Guerard **(Group A)**
Chairman of the Board, and Chief
Executive Officer
Sobeco Inc.
505, Boulevard René Levesque, West
Montréal, Québec
H2Z 1Y7
(514) 878-9090
(514) 875-2673 fax

Dr. Art Hanson **(Group C)**
President and Chief Executive Officer
International Institute for Sustainable
Development
212 McDermot Avenue
Winnipeg, Manitoba
(204) 958-7700
(204) 958-7710 fax

Professor Ken Hare **(Group B)**
301 Lakeshore Road West
Oakville, Ontario
L8K 1G2
(416) 849-1374
(416) 849-4954 fax

Mr. Jim Harries **(Group A)**
Manager, Policy Development
Insurance Bureau of Canada
181 University Ave
13th floor
Toronto, Ontario
M5H 3M7
(416) 362-2031
(416) 361- 5952 fax

Mr. Howard Hart **(Group B)**
Canadian Pulp and Paper Association
1155 Metcalfe Street, 19th Floor
Montreal, Quebec
H3B 4T6
(514) 866-6621
(514) 866-3035 fax

Ms. Jane Hawkrigg **(Group C)**
President
Jane Hawkrigg Enterprises Ltd.
401 Sheddon Avenue
Oakville, Ontario
L6J 1Y1
(416) 842-4149 Phone/Fax

Professor John Helliwell **(Group B)**
MacKenzie King Professor of Canadian Studies
Centre for International Affairs
Harward University
1737 Cambridge Street
Cambridge, Mass.
USA 02138
(617) 495-4253
(617) 868-8215 fax

Dr. W. David Hopper **(Group C)**
Senior Vice-President
Haldor Topsoe Inc.
915 - 15th Street N.W.
8th Floor
Washington, D.C.
20005
(202) 783-0112
(202) 783-1044 fax

Mr. John E. Houghton **(Group C)**
Chairman
Quebec and Ontario Paper Company Ltd.
80 King Street
St. Catherine, Ontario
L2R 7G2
(416) 641-4337
(416) 641-4332 fax

Mr. Michael Jeffery **(Group C)**
Solicitor
Fraser and Beatty
1 First Canada Place
39th floor
Toronto, Ontario
M5X 1B2
(416) 863-4511
(416) 863-4592 fax

Mr. Naresh Karnick**(Group A)**
Credit Policy
Royal Bank of Canada
Royal Bank Plaza
South Tower, 8th floor
200 Bay Street
Toronto, Ontario
M5J 2J5
(416) 974-6250
(416) 974-6023 fax

Mike Kelly **(Group A)**
Policy Advisor, Task Force on Tools
NRTEE

Dr. Margaret Kerr **(Group C)**
Vice-President
Environment, Health and Safety
Northern Telecom Limited
3 Robert Speck Parkway
Mississauga, Ontario
L4Z 2G5
(416) 566-3021
(416) 566-3038 fax

Mr. Claude André Lachance **(Group C)**
Dow Canada
1440 - 45 O'Connor Street
Ottawa, Ontario
K1P 1A4
(613) 230-5400
(613) 563-7822 fax

Dr. Richard Lipsey **(Group B)**
Director
Economic Growth and Policy
Program/CIAR
515 West Hastings Street
Vancouver, British Columbia
V6B 5K3
(604) 291-5036
(604) 291-5034 fax

The Honourable Donald S. MacDonald
c/o Ms Henie Price
McCarthy Tetrault
P.O. Box 48
Toronto Dominion Bank Tower
Toronto Dominion Centre
55 King Street West
Toronto, Ontario
M5K 1E6
(416) 362-1812
(416) 868-1793 fax

Mr. Peter Maurice **(Group A)**
President & CEO
Canada Trust
161 Bay Street
35th Floor
Toronto, Ontario
M5J 2T2
(416) 869-6100
(416) 361-8560 fax

Mrs. Judith Maxwell **(Group B)**
Chairman
Economic Council of Canada
18th Floor, Tower A
Place de Ville
320 Queen Street
P.O. Box 527
Ottawa, Ontario
K1P 5V6
(613) 952-1706
(613) 952-2171 fax

Mr. David Morton **(Group B)**
Chair and Chief Executive Officer
Alcan Aluminium
1188 Sherbrooke Street West
Montreal, Quebec
H3A 3G2
(514) 848-8501
(514)848-1528 fax

Gene Nyberg **(Group C)**
Corporate Secretary
NRTEE

Mr. Martin Palleson **(Group B)**
Ferguson Gifford
Suite 500 - Park Place
666 Burrard Street
Vancouver, British Columbia
V6C 3H3
(604) 687-3216
(604) 683-2780 fax

Ms. Abby Podhy **(Group A)**
Administrative Manager
Ontario Round Table on the Enviornment and the Economy
790 Bay Street, Suite 1002
Toronto, Ontario
M7A 1Y7
(416) 327-2077
(416) 327-2197 fax

Ms. Sarah Richardson (Round C)
2200 Yonge Street, 5th floor
Toronto, Ontario
M4S 2C6
(416) 324-7373
(416) 324-7380 fax

Mr. Don Roberts **(Group B)**
Levesque Beaubien
1155 Metcalfe Street
Montreal, Quebec
H3B 3S9
(514) 879-2333
(514) 879-5137 fax

Professor Abraham Rotstein **(Group C)**
Department of Economics
University of Toronto
150 St. George Street
Toronto, Ontario
M5S 1A1
(416) 978-4072
(416) 978-6713 fax

Mr. David Runnalls
Director, Environment and Sustainable Development Program
250 Albert St., Suite 1360
Ottawa, Ontario
K1P 5E6
(613) 238-2296
(613) 238-8515 fax

Barry Sadler **(Group B)**
1631 Barksdale Drive
Victoria, British Columbia
V8N 5A8
(604) 477-0119
(604) 477-8752 fax/phone

Mr. Larry Solomon **(Group A)**
Research Coordinator
Energy Probe
225 Brunswick Avenue
Toronto, Ontario
M5S 2M6
(416) 964-9223
(416) 964-8239 fax

L. Slater (c)
Environment Canada

Professor William Stanbury **(Group A)**
Commerce and Business Administration
University of British Columbia
2053 Main Mall
Vancouver, British Columbia
V6T 1Z2
(604) 822-8489 fax

Mr. Andrew Steer **(Group B)**
World Bank
1818 H Street NW
Room 55033
Washington, D.C.
20433
(202) 473-3299
(202) 477-0565 fax

Steve Thompson **(Group B)**
Senior Associate
NRTEE

Ms. Susan Tanner **(Group A)**
Executive Director
Friends of the Earth
251 Laurier Ave West
Suite 701
Ottawa, Ontario
K1P 5J6
(613) 230-3352
(613) 232-4354 fax

Mr. Fraser Wilson **(Group A)**
Ernst & Young Consulting
P.O. Box 251
Royal Trust Tower
Toronto Dominion Center
Toronto, Ontario
M5K 1J7
(416) 864-1212
(416) 864-1174 fax

Mr. Howard Wilson **(Group C)**
Executive Director
Prosperity Secretariat
235 Queen Street
2nd floor
Ottawa, Ontario

Total: 53

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SUSTAINABILITY AND PROSPERITY:

THE ROLE OF INFORMATION INFRASTRUCTURE

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Jack Ruitenbeek
H.J. Ruitenbeek Resource Consulting Limited
RR#2, Site 52
Gabriola, BC V0R 1X0
Tel (604) 247-8436
Fax (604) 247-8492

Daryl Fields
ARA Consulting Group Inc.
402 - 475 Howe Street
Vancouver, BC V6C 2B3
Tel (604) 681-7577
Fax (604 669-7390

Abstract

This paper highlights the changing role of infrastructure as Canada enters an era characterized by increased globalization of outlook, decentralization of production and decision-making, and rapidly merging technological media in the communications and information technology (C&IT) industry. The primary purpose of the paper is to identify a number of key issues and tensions that permeate infrastructure planning in the search for an economically prosperous and environmentally and socially sustainable society.

The paper examines physical and information infrastructure separately. The section on information infrastructure explores key issues related to the right of access to information and information infrastructure, the pace of deregulation in the industry, and the impacts on employment and job quality. It also identifies one area of key importance to sustainability which has been neglected by most current programs in Canada: the need to address the raw material requirements and waste generation implications of an industry characterized by rapid technological change, short product life, and declining costs that discourage recycling and reclamation. The section on physical infrastructure reviews the status and role of three segments of the physical infrastructure stock: transportation, energy and "environmental utilities". Within each segment, specific areas of complementarity and tension between planning for economic prosperity and planning for environmental sustainability are identified. The linkages between physical and information infrastructure are also addressed. Although the linkages cannot be definitely characterized, the paper identifies possible positive synergies. It also warns against regarding information infrastructure as a panacea.

The paper concludes with a discussion of seven themes that weave across all segments of physical infrastructure: the concept of "doing more for less", the role of economic signals and full cost accounting, decentralized decision-making, the role of the private sector, public involvement and management of research and development.

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INTRODUCTION

The Changing Role of Infrastructure

When we think of infrastructure, we typically think of roads, railways, ports, communication grids or other massive steel and concrete structures. They exude permanence; they seem unchangeable. We seldom get introspective about such infrastructure. It is, more often than not, regarded as a simple convenience or necessity to the pleasures and tasks of our day-to-day business.

But infrastructure is far from being a fixed entity; infrastructure technologies continue to change. The connotation that infrastructure is a static immutable entity is especially far off the mark today; some have likened the current communications technology revolution to the advent of powered flight, or to the introduction of the telephone. Infrastructure's role in society has been both a reflection of and a motivation of social change.

We distinguish here between *physical infrastructure* – that used for delivering goods and people – and *information infrastructure* – that used for delivering services. The changing role of both of these types of infrastructure is being driven by three key trends (Figure 1):

- **Globalization of Outlook.** Concerns now extend beyond simply the nation state or the individual, to the local community, the global community, and the supporting natural environment.

- **Decentralization of Production and Decision-Making.** Economic production and different forms of decision-making are no longer vested in or controlled by an elite.

- **Merging of Communications Technologies.** Broadcast, print, and computer technologies – all of which started as discrete technologies – are becoming increasingly merged into single integrated technologies.

In short, there are a number of pressures that are carrying us towards an *integrated global society through decentralization.* This paper explores how this premise influences the issues which mold physical and information infrastructure, and which will in turn have specific implications for Canada's economic prosperity and overall sustainability.

Decentralization – A Driving Force

The visionary trend of globalization is one primarily of outlook. It becomes explicit, however, in observable trends to greater decentralization in some areas. This decentralization is key to many of the issues explored in this paper, and it has many dimensions:

FIGURE 1
THE CHANGING ROLE OF INFRASTRUCTURE

	TRADITIONAL	MODERN	POST-MODERN
MOTIVATION	Political Defense	Economic Prosperity	Prosperity & Sustainability
SOCIAL FOCUS	"The State"	"The Individual"	"Global Community"
MODE OF ECONOMIC PRODUCTION	Hierarchical Centralized Discrete Technologies & Activities	Hierarchical Decentralized Discrete Technologies & Activities	Web More Decentralized Merged Technologies & Activities
GENERAL ROLE OF INFRASTRUCTURE	"Nation Building"	"Factor of Efficient Production"	"Factor of Sustainable Production"
PHYSICAL INFRASTRUCTURE FOCUS	Strategic Delivery of Goods & People	Efficient Delivery of Goods & People	Efficient Delivery, Ensuring Fair Access and Minimal Environmental Impact
INFORMATION INFRASTRUCTURE FOCUS	Strategic Establishment of a Communications Network	Efficient Delivery of Multiple Discrete Services	Efficient Delivery of Multiple Merged Services, Ensuring Fair Access
KEY TRENDS	⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒ **Globalization of Outlook** ⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒ **Decentralization of Production and Decision-Making** ⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒ **Merging of Communications Technologies** ⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒⇒		

- **Decentralization of Location.** The production and consumption of goods and services are becoming less spatially concentrated. Scarce land resources, higher capital and labour mobility, and concomitant technological change are causing changes in where we work and where we live.

- **Decentralization in Time.** Production and consumption are, similarly, becoming less temporally concentrated. The nation, and the world, operates seven days a week and twenty-four hours a day.

- **Decentralization of Productive Activity.** Specialized product development continues to occur when and where local comparative advantages arise.

- **Empowerment.** Social, political, and economic structures are changing to allow individuals greater freedom and participation in guiding their lives.

- **Decentralization of Decision-Making Within Structures.** In business especially, traditional forms of hierarchical decision-making are disappearing and becoming "flatter". Within organizations decision-making is decentralized to the group of people that the decisions will affect.

The overall issue of decentralization is, however, quite complex and there are other forces at work that promote the concentration of activity and the centralization of decision-making authority. Social settlement patterns, for example, persist in causing greater rates of urbanization. Also, the creation of activity "hubs" continues even in the face of increased communication and transportation options (Nilles, et al., 1976).[1] Moreover, certain types of control is – arguably – becoming concentrated as multinational firms increase their influence to more parts of the globe. The decentralization trend, therefore, may be more precisely characterized as one of 'selective' decentralization, with counter-trends that allow a concentration of control in selected regions or firms. The assumptions in this paper, however, are that – even though there is a potential for greater centralized control – over the longer term this control in itself becomes more diffused and decentralized *within* the decision-making structures. Numerous examples of this are available with large companies having branch offices and production facilities all over the globe; the most successful of these are the ones which have decentralized decision-making authority within the larger corporate umbrella (Reich, 1991).

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[1] Even with advanced communications, most available evidence suggests that massive concentrations of activity will still continue to exist, as companies attempt to take advantage of locating at key urban hubs. Communication technologies will continue to favour high volume point-to-point transmission between such hubs. Hence, companies do find that there are strategic and economic advantages to locating near these centres: the cities of New York, London, and Tokyo are examples of where this is occurring internationally. It is therefore not likely that we shall see a complete exodus of workers from the city cores to the suburbs and the country-sides. What is more likely is that there will be a partial decentralization, favouring those tasks that do not require constant physical contact with the central work and production activities.

From Prosperity to Sustainability – Changing Motivations

Underlying the decentralization of production and decision-making, the motivations behind infrastructure design and focus have also been changing (Figure 1). Traditionally, when the social focus was on the nation state, infrastructure's role was to defend or expand the state. Strategic, military, or colonial aspirations were the motivating forces behind many infrastructure projects: from the Roman roads to the Alaska Highway.

While some of these motivations persist, the advent of the modern era (after the Industrial Revolution) changed the social focus and the economic importance of infrastructure. Social changes stressed individual freedoms; economic changes stressed efficient production and prosperity. At this stage, physical and information infrastructure became critical factors of economic production: the challenge was to design and organize this infrastructure in a manner that it could deliver goods, people, and services cost-effectively and reliably. Public expenditures on physical infrastructure construction had the added role of job creation as a counter-cyclical recession-fighting mechanism. Promotion of information infrastructure had a social role of supporting freedom of expression and other rights consistent with the principles of participatory democracy.

The post-industrial revolution era is bringing further changes to social, political and economic motivations. Concentrating solely on *economic prosperity* is no longer an adequate motivation: concerns for the global community, and for future generations, have added the new motivation of *sustainability*. The general role of infrastructure is thus changing from one of a factor of *efficient* production to one of a factor of *sustainable* production. The sustainability angle has added important environmental and social dimensions. The job creation role of massive public works has been brought into question if it undermines long-term economic prospects because of increased debt loads and taxation levels. *Environmental impacts* of all infrastructure developments are becoming an increasingly important concern. *Fair access* to both physical and information infrastructure is regarded as necessary to ensure a socially and politically sustainable society: it provides the freedom of movement and the freedom of expression that many feel are prerequisites for the longevity of society's structures.

While strategic defense and economic prosperity will continue to be part of the set of motivating forces behind changes to physical and information infrastructure, greater preoccupation with sustainability will shape much of infrastructure planning over the next century.

Purpose of the Paper

Through the evolution of the role of infrastructure, fundamental linkages between prosperity and sustainability have become apparent. Each policy philosophy recognizes economic, social and environmental needs of society. Yet the fear that environmental protection will impose costs on the economic system and compromise competitiveness persists in some quarters and the threat of an infrastructure repair bill in the order of $20 billion nationally raises concerns regarding the allocation of scarce public investment funds between competing needs. Tensions between

cost minimization and environmental protection or fair access issues do exist; however, complementarities can be found.

The purpose of this paper is to explore the linkages between infrastructure, prosperity and sustainability and to describe potential complementarities and tensions that planners will have to face in making investments for sustainability.

Outline of the Paper

This paper investigates key sustainability and prosperity issues in four separate areas:[2] physical infrastructure (transportation infrastructure, energy infrastructure, environmental utilities) in Part A and information infrastructure in Part B. Each part addresses general observations and challenges that face decision-makers as they pursue both prosperity and sustainability. Following the investigation of each of the four infrastructure components, the paper investigates some of the important linkages that exist among different types of infrastructure, in particular between information infrastructure and other forms of physical infrastructure (Part C).

In discussing each of these components, the paper emphasizes the potential complementarities and tensions among economic, environmental, and social priorities. In the case of the physical infrastructure components of transportation, energy and environmental utilities, the focus is on the economic and environmental trade-offs because our physical infrastructure heritage is largely the product of economic (prosperity) and health imperatives. Unlike information infrastructure, which is frequently attributed with environmental improvements, physical infrastructure decisions have traditionally omitted environmental considerations. Challenges to decision-makers, therefore, lie in incorporating environmental imperatives more fully into the planning framework for physical infrastructure.

In the case of information infrastructure, key sustainability concerns tend to focus on social sustainability issues, environmental sustainability impacts within the sector, and environmental sustainability complementarities and tensions acting through linkages with forms of physical infrastructure. A key challenge for decision-makers is not to fall into a trap that regards information infrastructure as a panacea. Although the historical environmental tensions within the sector have not been widespread, social challenges presented by expansion of information infrastructure are manifold. Further, there is significant potential for future environmental tensions primarily because of rapid sector growth which encourages short product lives, the use of rare raw material inputs, and falling costs that encourage high material throughputs. The main policy challenge, however, will be to take advantage of beneficial linkages between information and physical infrastructure and to minimize the instances where expansions in information infrastructure lead to a proliferation of environmentally unsound physical infrastructure.

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[2] The terminology we use closely relates prosperity to economics and sustainability to environmental protection and social issues.

Part D of the paper has two sections One section identifies a number of key themes for sustainability that are common across all segments of infrastructure. These themes concentrate on the role of pricing and appropriate signals for sustainability and economic prosperity, but recognizes common themes related to decision-making and research and development. A concluding section presents a number of opportunities and challenges to decision-makers.

Each of the segments of infrastructure covered in this paper deserves much more detailed examination than can be presented here. Transportation planning, for example, raises a vast array of complexities that can only be alluded to within the constraints of this paper. The purpose here is to set out ideas for joint planning for prosperity and sustainability and explore how infrastructure may be designed differently to meet both sets of needs.

PART A:

PHYSICAL INFRASTRUCTURE

PHYSICAL INFRASTRUCTURE

INTRODUCTION

The state of a country's physical infrastructure is a critical ingredient in the economic, social and environmental welfare of its citizens. Yet Canada's infrastructure is aging. The Canadian Federation of Municipalities estimates a bill of $20 billion to replace and repair the existing stock. Furthermore, physical infrastructure decisions have traditionally omitted environmental considerations, generating pressures on the quality of air, water and other environmental resources.

In this section of the paper, we explore physical infrastructure needs and emphasize the complementarities and tensions between environmental and economic priorities. We first look at transportation infrastructure, followed by energy infrastructure and environmental utilities.

TRANSPORTATION INFRASTRUCTURE

When the term "infrastructure" is used, many people immediately think of how we move from one location to another -- they think of transportation routes, railways, airports, and shipping. Indeed, transportation infrastructure has played a critical role in the political, social and economic development of Canada, from the construction of the canal network on the St. Lawrence River, to the completion of the transcontinental railway, to the existing network of international and regional airports.

Canada's Existing Transportation Infrastructure

Canada's transportation infrastructure is dominated by roads and highways. The road infrastructure includes over 825,000 km and more than 48,000 bridges. Most of the road system (64%) falls under municipal jurisdiction, but the main road linkages between major centres fall under the jurisdiction of the provincial (34%) or federal (2%) governments.

Marine transportation is the single most important mode of transport in terms of total freight tonnage carried, largely because it is one of the main modes for moving bulk commodities such as forest products, grains and ores. The Great Lakes shipping system is important, but about 97% of all international container traffic is handled through Montreal/Contrecoeur, Halifax or Vancouver.

Rail transport is also mainly devoted to shipments of bulk commodities. The rail infrastructure in Canada consists of about 91,500 km of track and almost 4000 locomotives, 77% of which are devoted to freight service. Yet, the role of rail transport has diminished over time, with abandonment of 2100 km of track between 1987 and 1989.

By contrast, air transportation is a growing sector with a 6.5% increase in total tonne-km in 1989 over the previous year. Canada's air infrastructure supports the movement of almost 38,000 passengers and 658 million tonnes of cargo annually. The number of aircraft movements at about 60 Transport Canada airports totalled close to 6 million in 1989. The five busiest airports were Pearson International (350,000 movements), Vancouver International (325,000), Montreal International (225,000) Calgary International (210,000) and Victoria International (200,000) (TAC, 1991b).

The Economic Role of Transportation Infrastructure

The economic role of transportation infrastructure is conceptually simple. Productivity, a key element in economic growth, is closely linked with the rate of capital investment; public infrastructure, including transportation infrastructure, is part of the capital stock. Transportation infrastructure, therefore, is a vital factor of production, and its availability and quality will affect costs of production. More specifically, investments in transportation infrastructure can reduce

resource costs to users in the form of improved accessibility, reductions in travel time, lower operating costs, and reduced accident costs.

It has recently been suggested that these "user benefits" do not fully capture the benefits of transportation infrastructure. The Transportation Research Board of the U.S. National Research Council is currently exploring productivity impacts associated with infrastructure-related structural change in industry. These impacts include reorganization of corporate logistics and distribution networks based on the capabilities of the transportation system. Reorganization can include the adoption of "just-in-time" inventory management, elimination of distribution centres, and clustering fewer depots around key points in a transportation network (Transportation Research Board, 1991).[3]

Prosperity Issues

Some of the prosperity issues currently facing transportation infrastructure are:

- appropriateness of transportation infrastructure mix;
- maintenance of the roadway infrastructure;
- highway financing; and
- congestion.

Infrastructure Mix: The appropriateness of the infrastructure mix involves both mode of transport and accessibility. As the Canadian economy adapts to shifting trade links in more knowledge-intensive industries and services, the relative importance of different transportation corridors (e.g., east-west vs. north-south) and modes (e.g., passenger vs. goods) may also shift.

Increasing concerns for the demand on and system capacity for inter-city passenger transportation, for example, has led to the Royal Commission on National Passenger Transportation. The Commission, which submitted its interim report in April, 1991, has identified a number of key economic, social and demographic issues, including tradeoffs between road and rail (including the prospect of high-speed rail) and improvements and challenges of intermodal integration. Intermodal integration has also been raised as a key element in future freight transportation systems.

Maintenance of the Roadway Infrastructure: The Road and Transportation Association of Canada paints a gloomy picture of the future of Canada's road infrastructure. Having estimated that "current spending levels are almost $2 billion annually under what they need to be *just to maintain existing service and surface condition levels at what they were in 1978 -- without allowing for further growth*" (RTAC, 1990), the report goes on to suggest that this spending shortfall will result in reduced service levels, increased vehicle costs, increased maintenance

[3] The linkages between economic growth and infrastructure investment financed through tax revenues are not without controversy; some economic studies suggest that government spending has a negative impact on growth (Jorgenson, no date).

costs and compromised road safety, and will ultimately compromise industrial development and Canada's competitiveness with U.S. producers.

Maintenance of the existing roadway infrastructure is at the root of a second major national transportation policy initiative: the National Highway Policy for Canada. The policy is being developed under the auspices of the Council of Ministers Responsible for Transportation and Highway Safety. The project's Phase I Report summarizes the context for a National Highways Policy as follows:

> In the past several years, growing recognition of the importance of highway transportation to the Canadian economy has been linked with serious concerns for the preservation of the Canadian highway infrastructure. Economic development in the traditional centres of Canadian manufacturing as well as the resurgence of the peripheral resource-based economy have begun to move highway transportation problems to a national level (Council for Ministers Responsible for Transportation and Highway Safety, 1988).

Two surveys undertaken for the policy initiative quantified deficiencies in the national highways system.[4] These deficiencies were:

- 33% of the system is below minimum geometric design standards;
- 18% of the system has serviceability deficiencies (i.e., could not support a 90 km/h operating speed under normal conditions or are below the appropriate local standard); and
- 26% of the system falls below the minimum standard for pavement strength and quality.

Combining serviceability and pavement deficiencies, the surveys concluded that about 38% of the National Highway System is below at least one minimum standard. In addition, deficiencies (including load restrictions, vertical clearance deficiencies and requirements for major strengthening or repair) affect about one third of the total number of bridges in the system.

The economic benefits of these improvements include reduced accident costs, vehicle operating savings and travel time savings. The National Highway Policy Study Steering Committee Report -- Phase 2 reported an estimate of user benefits in the range of $17 billion over 25 years. This figure excludes implications of cost savings for "[enhancing] the competitiveness of Canadian industries", the benefits associated with "better market integration" with the United States and increased tourist traffic (National Highways Policy Steering Committee, 1989). At a 5%

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[4] One of the first tasks of the Steering Committee for the National Highway Policy was to identify a national highway system. Based on a number of criteria, they identified a national system of 24,459 highway kilometres in length with 3,534 bridges. The system represents approximately 16% of the freeway, arterial and collector highway infrastructure under direct provincial or federal jurisdiction, and about 3% of total road length in Canada (when local and municipal roads are considered). The routes that were included in the national highway System are those that form a primary interprovincial or international link or directly link major population/commercial centres in a province or territory.

discount rate, the value of quantifiable benefits exceeds costs, although benefits fall just short of costs assuming a 10% discount rate.

Highway Financing: Highway financing is one of the most controversial and complex issues currently facing transportation managers. An urgency in the debate is fuelled by a need to find funds for maintenance investments against the priority accorded to deficit reduction at all levels of government. Questions brought forward by the railroad industry regarding the efficiency and equity of current financing methods (e.g., are truckers paying their way?) have also contributed to the discussion.

There is a fair degree of consensus in the literature about the economic principles upon which highway financing should be based: namely that user charges should be based on the marginal cost of the services provided; and that charges should not favour one mode or class of highway user over others (i.e., the concept of competitive neutrality). The complexities arise in application of the economic principles and, specifically, problems related to the definition of costs, the allocation of cost components to users, and equity considerations associated with the design of user charges (Bisson, 1989). Reconciliation of some of these issues will be further complicated by the potential influence of interest groups.

Congestion: As noted in both the Royal Commission on National Passenger Transportation and the work undertaken for the National Highway Policy for Canada, congestion, especially in the urban areas, is fast becoming a major concern.

Costs of congestion include direct costs of travel (time and reliability) as well as indirect costs. For example, Ulberg (1991) shows that implicit parking subsidies in the United States could exceed $30 billion per year; a portion of those costs are borne by businesses in the form of employer-subsidized parking.[5] By compromising reliability, congestion can also affect the viability of efficient inventory management systems, such as "just-in-time".

The prosperity planner's prescripts for transportation, then, include:

- direct capital projects to modes and corridors that reflect emerging patterns of economic growth;
- protect the productivity and viability of the existing roadway infrastructure through adequate maintenance;
- develop fair and efficient methods of highway financing; and
- develop approaches to minimize urban traffic congestion.

[5] It is estimated that approximately 50% of parking in downtown Vancouver is employer-subsidized.

Environmental Issues

Most of the environmental urgency in the transportation sector focuses on road transportation. This urgency has been driven by the fact that vehicles are the largest source of key air pollutants (compared to air transport, rail, marine) and present problems related to surface and groundwater quality, waste management and noise.

The environmental concerns are particularly acute in urban areas because of the concentration of vehicular activity. At the rural or regional level, land use concerns and wildlife impacts also come into play. Regionally and locally, carbon dioxide emissions and depletion of non-renewable resources as transportation fuel are also of concern from the perspective of sustainability, as are road maintenance practices such as de-icing and asphalt spreading.

Considerable effort has been devoted to examining management options for transportation, and specifically, road transportation. These options fall into five categories:

- traffic demand management;
- vehicle energy emission;
- trip reduction;
- interfuel substitution; and
- intermodal shifts.

Examples of measures that fall into each of these categories are presented in Figure 2.[6] These measures have direct implications for infrastructure. For example, a number of traffic demand management measures will involve introduction of new technologies for road management systems; and land use planning and intermodal shifts have obvious implications for physical transportation infrastructure.

From the perspective of environmental sustainability, the basic planning precepts may be roughly compartmentalized as:

- restricting or conserving transportation services, including redefining what needs to be moved;
- adapting the infrastructure for alternative modes of transportation; and
- enhancing the efficiency of transportation where "reducing" is not feasible (e.g., all measures to increase energy efficiency).

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[6] A number of these measures, particularly in the areas of interfuel substitution and traffic demand management, are evolving. For example, a number of technological barriers face the widespread introduction of electric vehicles, and interactive vehicle/highway systems (IVHS) are in their infancy. Other measures will demand significant behavioral changes and, on another level, the policy choices for implementing measures (e.g., regulation versus economic instruments) will have important impacts.

FIGURE 2: EXAMPLES OF TRANSPORTATION MANAGEMENT MEASURES

Traffic Demand Management	Route and traffic planning Driver training High occupancy lanes IVHS Computerized traffic control systems Freeway traffic management systems Pricing mechanisms
Vehicle Energy Efficiency	Fuel efficiency Vehicle maintenance Vehicle retrofits
Trip Reduction	Land use planning Consolidated work week Staggered working hours Ridesharing Parking policy Telecommuting Pricing mechanisms
Intermodal Shifts	Road to rail Public transit Bicycling
Interfuel Substitution	

Complementarities and Tensions

The relationship between economic prosperity and environmental sustainability is complex. The critical role of transportation in economic growth and the array of environmental issues raised by the transportation sector are further complicated by the range of transportation choices and local factors and influences. However, certain elements of complementarity and tension can be identified.

At the urban level, congestion is a problem from both economic and environmental perspectives, and opportunities to develop a package of measures to deal with the joint problem exist. Demand management, trip reduction measures, and intermodal substitution can help to reduce

vehicle emissions while easing land pressure and some of the time and reliability costs that impinge on economic productivity.

Transportation infrastructure cannot be considered in isolation from urban or land use planning or city structures. Alternative structures have been proposed to reduce urban transportation needs (and infrastructure), with the most common emphasis on high density planning either in a central core or nodal configuration, and self-contained communities that require people to move shorter distances and that open up possibilities for alternative transportation modes.

A recent study for the Greater Toronto Coordinating Committee examined three main urban structure concepts for the Greater Toronto Area. The three concepts were:

- Spread concept that represented the status quo for the area: that is, growth in the suburban regions at relatively low density and continued concentration of office development downtown;

- Central concept with intensification within the central core and reduced growth outside existing urban boundaries; and

- Nodal concept in which residential and commercial growth is concentrated in and around existing communities, with little spread outside those communities.

Among the criteria for comparing the three concepts were infrastructure costs, transportation requirements and economic impetus. The report concluded that the spread concept is least compatible with sustainable development "as it would consume the greatest amount of rural land and related agricultural productivity and natural resources, would use the most energy and produce the most air pollution" (IBI Group, 1990).

The study also indicated that transportation operating costs would be higher in the spread concept but did not find significant differences in terms of infrastructure capital costs. Although the study did not compare broad corporate operating costs, location decisions and transportation requirements, the initial cost estimates do not rule out opportunities for urban planning to simultaneously attend to environmental and economic needs.

Management of urban traffic congestion is a world-wide issue and new technologies to deal with the problem offer Canadian innovators opportunities to develop external markets. As noted by the Ontario Round Table on Environment and Economy (1991b), Canada can build on an existing reputation in the area of alternative fuels and the development of technology for accessible transit, light rapid transit, alternatively fuelled transit vehicles, infra-red emission scanning equipment and fleet management control systems. This complementarity in the field of transportation technology, mirrors a general complementarity that exists between prosperity and sustainability: developing environmentally friendly products and technologies for a world wide-market.

Complementarities also exist at the intercity or regional level. One of the key issues for both sustainability and prosperity is energy efficiency. From the prosperity perspective, of course, energy efficiency contributes to lower costs. The link with environmental protection is similarly obvious: using less energy generates less waste. One joint planning priority, then, would be to maintain key intercity corridors at peak efficiency and to augment that infrastructure with ancillary services that promote energy efficiency (e.g., vehicle inspection, driver training).

One tension between environmental sustainability and economic prosperity is the relative role of road transportation. The dominance of road transportation in Canada is driven by cost, geography, density considerations and government policies. From an environmental perspective, however, alternative modes may be more sustainable than the motor vehicle. With respect to the choice of freight modes, intermodality -- the combination of rail for long distance movement of bulk goods and road for short distance of the same goods -- may be the most suitable option (Ontario Round Table on Environment and Economy, 1991b). As suggested above, research into methods of highway financing may shed light on the role of prices in modal choice. If research indicates that road charges fall short of marginal costs, then a realignment of prices based on economic principles may shift demand to other modes from which a more environmentally benign transportation infrastructure may emerge.

If the current dependence on road transportation has emerged from economic considerations, it is possible that any shift to an inter-modal transportation network may impose additional costs for some transportation users, with possible implications for competitiveness. A more aggressive move to new environmentally-friendly transportation modes (e.g., electric rail) could have similar effects. However, impacts of either policy are likely to differ significantly across applications, some of which may in fact generate benefits to some users.

Summary

Transportation services, as supported by transportation infrastructure, are critical to economic growth and prosperity. Transportation services allow the exchange of goods, and people, facilitate trade, and reduce the costs of production. Transportation is also key to some pressing environmental concerns. But environmental sustainability and economic prosperity have at least two areas of common and potentially complementary concerns: urban traffic congestion and energy efficiency.

In the area of modal choice, the complementarities are less clear. Developments in intermodal scheduling and logistics and highway financing may offer opportunities for economic benefits from integration, but the extent to which these economic benefits outweigh accessibility issues and costs of moving away from the existing system is less clear.

ENERGY INFRASTRUCTURE

Energy is an integral part of modern life and a critical component of Canadian infrastructure. Our endowment of considerable sources of energy has helped shape the economic profile of the country; along with Canada's climate and geography, the availability of energy has made Canada one of the most energy-intensive countries in the world.

However, there is considerable and growing awareness of the negative environmental implications of energy, extending from production through transportation and distribution to final use. These impacts affect land, air and water resources, with consequences for the health and well-being of Canada's citizenry and the productivity of our natural resources. In addition, there are concerns about dependence on non-renewable forms of energy, especially the use of oil in the transportation sector.

Directions for Sustainability

Both the Ontario and the B.C. Round Tables on Environment and Economy have produced sector papers on energy. While the two documents do not completely overlap, they do present similar themes for sustainability. These are discussed below.

Energy Efficiency: Energy efficiency falls under the general rubric of "doing more for less". As noted by the B.C. Round Table, "conserving energy and using energy more efficiently ... are the cornerstones of any sustainable energy strategy ... Energy efficiency is recognized around the world as one of the most effective and affordable means of controlling the environmental impacts of energy supply and use" (B.C. Round Table on Environment and Economy, 1992a).

For example, measures to manage global climate change (specifically, carbon dioxide emissions) focus on energy conservation and energy efficiency improvements in the industrial, residential and commercial sectors (ARA Consulting, 1992; U.S. EPA, 1990). With new energy technology, energy savings in specific uses ranging from 20% to 50% are not unheard of (Buderi, 1991).

Energy Technology: Both the Ontario and B.C. Round Tables pay particular attention to the role of energy technology in a strategy for sustainability. Energy technologies address alternative sources of energy (e.g., biomass energy, fuel cells, hydrogen, ocean energy, solar power) as well as demand management and environmental control technology. It is generally held that technology could provide important answers to environmental sustainability.

The more pressing questions relate to the management of research and development and the balance of R&D between traditional and non-traditional (and more environmentally benign) sources of energy. The Ontario Round Table recommends more "balanced incentives" for new technology development and application, in particular for low carbon and renewable energy

technology, including pursuit of longer term opportunities such as fission. These incentives would include improvements to or refinement of approval processes for smaller scale energy developments, pricing adjustments (discussed below), consumer education regarding technology and energy efficient products and services, and a reassessment of the distribution of public funds for energy research and development (Ontario Round Table on Environment and Economy, 1991a).

For example, the federal government's main energy R&D program -- the Panel on Energy Research and Development (PERD) -- devoted 50% of program funds to oil and gas over the five year period 1985/86 to 1989/90 and an additional 15% to coal. The remaining 35% was devoted to renewables (19%), electricity (6%) and fusion (10%). By another breakdown, 60% of program funds were allocated to R&D related to production compared with 20% for energy efficiency, 12% for energy usage and 8% for transportation research (ARA Consulting, 1991). The federal government also supports nuclear energy research through the Atomic Energy of Canada Ltd. (AECL) which biases total research spending in favour of energy production even more. Public R&D funding programs are designed to meet a multitude of objectives and policy priorities; however, the PERD and AECL examples suggest that existing R&D programs may not fully incorporate the needs for sustainability or the potential complementarities between sustainability and prosperity.

Decision-Making: A number of issues were raised by the Round Table with respect to decision-making in the energy arena. Perhaps first and foremost is a call for greater public involvement at all stages of energy-decision making: setting public policy goals, developing plans, assessing project proposals and reviewing project implementation. Part and parcel of more extensive public involvement are:

- ensuring that mechanisms to facilitate multi-stakeholder input are well established;
- improving public information and education; and
- ensuring adequate financial support for broad participation by public interest groups.

Both Round Tables also call for a greater emphasis on comprehensive long range energy planning so that the complete energy infrastructure -- all energy types and all producers -- can be considered collectively in meeting the demand for energy services. It was also noted that this process would facilitate coordinated planning with other jurisdictions, so that international environmental issues (such as acid rain and global warming) could be addressed efficiently and effectively.

Finally, the Ontario Round Table (1991a) recommends that the provincial government "facilitate further deregulation and competition in the Ontario energy sector, rather than move to centralized planning and control". The perceived benefits of such decentralization would be to allow industry "a greater choice of supply sources including self-generation, private power and purchases from other utilities". In such a case, public power utilities would be responsible for operation of the power grid (transmission and distribution) only, analogous to the government's responsibility in other segments of public infrastructure such as the highway grid.

One of the key outcomes of the decentralization proposal would be increased competition amongst power generators and a move to competitive-based pricing. The primary advantage of this shift from a sustainability perspective relates to the allocation and use of resources. A move to competitive (market-based) pricing would represent a shift away from average cost pricing and cross-subsidization of different electricity sources, practices that have historically characterized public power utility policies. Because competitive-based pricing would take into account the cost of future sources of power, it would likely increase the price of electricity, at least for some fuel types. Increased prices would lead to conservation and reduced demand for new electricity projects and infrastructure. Competitive-based pricing could also result in a shift among fuel types and potential efficiency improvements on the supply side; the profit motive would impart considerable discipline on improving the efficiency with which energy is converted to electricity, with environmental benefits along the full path from energy production to final end use (N. Rubin, Energy Probe, pers. comm.).

A complementary component of decentralization is full cost accounting: inclusion of all environmental and social costs so that market-based price signals correctly reflect both the economic and environmental status of each energy source. Extending the full cost accounting concept to all energy forms (in addition to electricity) would shift relative prices of various energy forms and, consequently, gradually redefine the country's energy infrastructure.

Foundations for Prosperity

As noted above, the Canadian economy is energy-intensive. Figure 3 provides data on the energy intensity of a variety of industry groups. The exhibit also shows the share of Canadian exports by each industry group. As indicated, for approximately 30% of total Canadian exports fuel and electricity costs account for more than 5% of the value of shipments. A strong, reliable and efficient energy infrastructure, therefore, is critical to a large segment of the Canadian economy and any changes to that infrastructure are likely to be widely felt.

The energy-producing sector also plays a role in prosperity. Exports of refined petroleum and coal products account for about 10% of total Canadian exports (see Figure 3), which represents an increase from 6% in 1970. Major energy exports are crude oil and natural gas, primarily to the United States. Total energy exports amounted to $12.1 billion in 1986. The energy-producing sector accounts for about 2.7% of total employment in Canada, 6.1% of GDP and over 14% of investment spending (Energy Mines and Resources Canada, 1987).

Complementarities and Tensions

Prosperity and sustainability create a number of possible complementarities in energy policy development, as well as some fairly profound tensions. On the positive side, a world-wide focus on clean energy technologies affords an opportunity for the Canadian energy sector to develop new products and services to satisfy this growing demand.

FIGURE 3: ENERGY INTENSITY IN CANADIAN EXPORT INDUSTRIES

	Cost of Fuel and Electricity as Percent of Value of Shipments[a]	Share of Total Canadian Exports[b]
Food, Beverage & Tobacco Industries	0.7-2.4	9.1
Rubber, Plastic & Leather & Allied Products Industries	1.2-2.9	2.9
Textile & Clothing Industries	0.8-3.7	0.9
Wood, Furniture & Fixture Industries	1.4-3.5	5.1
Paper & Allied Products Industries[c]	10.4-17.3[d]	11.3
Refined Petroleum & Coal Products	1.4	10.1
Primary Metal Industry	6.5	8.6
Non-Metallic Mineral Products	9.8[e]	5.8
Machinery & Electrical & Electronics Products Industries	1.2-1.4	12.0
Transportation Equipment Industries	1.8	25.4
Chemical and Chemical Products Industries	7.1	4.5

Notes:

a 1984.
b Average 1988 - 1991.
c Excludes corrugated box industry.
d Underestimates energy intensity because excludes use of self-generated fuel and electricity.
e Energy intensity values for clay, cement and lime exceed 16%.

Sources: Statistics Canada, *Exports by Country*, (January-December, 1989, 1991)
Statistics Canada, *Manufacturing Industries of Canada: National and Provincial Areas*, Catalogue 31-203.

Canada's energy resources also include substantial resources of hydro-electric power and natural gas, two of the "cleaner" traditional energy sources. As environmental concerns world-wide (and particularly in the United States) increasingly affect investment decisions, the demand for these clean energy sources will rise. Although an economic opportunity, energy export policy will have to deal with geographic tradeoffs for environmental impacts (e.g., reductions in global carbon dioxide emissions compared to increased local wildlife and land disruptions associated with hydro developments) and social and political issues associated with exporting energy.

As noted above, one of the main policy options for carbon dioxide management is energy conservation. Many of the energy efficiency and energy conservation measures are expected to generate cost savings and, in this way, should contribute to economic competitiveness and prosperity as well as environmental enhancement. A similar argument could be made for potential efficiency improvements in the electric utility sector.

The fundamental tension between principles for sustainability and prosperity revolve around energy pricing. From a sustainability perspective, marginal cost pricing and general price increases can be justified on the grounds of conservation of resources and dampening of energy demand. From a prosperity perspective, any price increases could hamper competitiveness, especially given the energy-intensity of many of Canada's major export industries.

Sustainability also calls for an adjustment in *relative* prices of different energy sources to fully account for environmental and social costs. Irrespective of the change in average energy prices, a change in relative prices would result in fuel switching, with associated adjustment costs throughout the economy and distributional consequences in the energy-producing sector. Introduction of a carbon tax to reduce carbon dioxide emissions (the major greenhouse gas) illustrates these tensions. Results from a general equilibrium environment-economy model simulation showed that a carbon tax was the most cost-effective instrument to achieve carbon dioxide emission reductions; that is, a directly targeted tax on the carbon content of fuels resulted in a smaller decline in real income than did performance standards or an indirectly targeted tax on fossil fuels (Environment Canada, 1992).

On the other hand, the model simulation also indicated that the tax would result in a decline in real income by approximately 0.25%. A carbon tax could also significantly affect Canada's trade balance. Taxing carbon fuels that are used in the production of goods and services, as indicated above, is likely to increase the costs of those products; this would provide a cost advantage for imports unless an equivalent carbon tax is levied on all imports. A carbon tax would also add to the cost of exported goods, placing Canadian raw materials and manufactured goods at a disadvantage in international markets (Environment Canada, 1992).

Finally, a carbon tax could have important regional consequences. Coal, which has the highest carbon content of traditional fuels and, therefore, would suffer a heavier tax burden, is almost exclusively (80%) produced in Alberta and British Columbia. Reduced demand for coal through price effects could have economic prosperity implications for these provinces and, more specifically, for single industry towns supported by coal mining. In the electricity-generating sector, Saskatchewan and Alberta are virtually dependent on fossil fuel, as are the Atlantic

provinces. A carbon tax would place a regional disadvantage on these provinces, compared to Quebec, Ontario, Manitoba and British Columbia who enjoy varied sources of electric power, including hydro and nuclear.

Summary

Canada's energy infrastructure plays a fundamental role in both environmental sustainability and economic prosperity. Areas of mutually reinforcing action include energy conservation measures, development of clean energy technologies, and increased exports of "clean" energy sources.

However, a basic tension between environmental sustainability and economic prosperity cannot be overlooked; because of the important role of the energy-producing sector and energy-intensive export industries in the Canadian economy, increases in the absolute price of energy or shifts in the relative prices of different energy sources to reflect environmental impacts could have negative economic and regional development implications.

ENVIRONMENTAL UTILITIES

Infrastructure has traditionally encompassed the provision of drinking water, education and health facilities, waste management (sewage, liquid and solid waste), transportation, communications and public administration (including defence and policing). These "utilities" have developed in support of economic activity and social concerns. Recognition of environmental imperatives is leading us to reassess of our activities, products and serviced; no less so, our definition of infrastructure.

Needs for Sustainability

Environmental imperatives are shifting the composition of what we include in "infrastructure". Although the basic categories listed above have not changed, sustainability requires a substantive change in the content of these categories. Specific changes include (but are not be limited to):

- expanded water treatment facilities to deal with both the nature of water contamination problems and the environmental byproducts of the water treatment process;
- expanded sewage treatment facilities (secondary, post-secondary, tertiary treatment) and upgrades to meet tougher effluent and emission standards;
- expanded sewage treatment facilities to areas where they do not currently exist;
- waste management systems to manage special wastes, recyclable materials, and more stringent environmental standards for waste disposal sites and processes; and
- introduction and maintenance of environmental monitoring systems and policy development/implementation at municipal, regional, provincial and national levels.

Although incremental to the massive infrastructure already in place, these new requirements are not insignificant. For example, approximately $1 billion or 72% of capital expenditures projected by the Greater Vancouver Regional District for the 1991-1997 period, are allocated to improved environmental projects (GVRD, 1991). The bulk of the expenditures lie in implementation of secondary sewage treatment facilities (see Figure 4). Environmental initiatives will also raise operating costs by approximately 50%, or an additional $50 million per year.

Other municipalities and regional districts face similar environmental initiatives. For example, the National Capital Region approximately doubled residential water bills to finance post-secondary and tertiary sewage treatment facilities. The Green Plan, produced by Environment Canada in 1990, specifically referenced a significant acceleration of the provision of water and sewer systems to Indian reserves.

FIGURE 4: GREATER VANCOUVER REGIONAL DISTRICT LONG RANGE INVESTMENT AND OPERATIONS PLAN

	Capital Expenditures 1991-1997	Operating Costs (annual, on completion)
Sewerage and Drainage		
• Legislated programs	644.6	18.3
• Maintenance and replacement	110.2	23.4
• Growth	46.4	0.6
• Board policies	225.0	5.9
Sub-Total	1,026.2	48.1
Solid Waste		
• Legislated programs	3.7	
• Board policies	12.6	
• Maintenance	102.0	
Sub-Total	118.3	37.7
Drinking Water		
• Committed new projects	35.8	0.1
• Legislated/mandated projects	27.5	0.1
• Maintenance and growth	122.1	12.8
• Enhanced reliability	26.8	-
• Board policies	99.0	6.4
Sub-Total	311.2	19.3
Air Quality	n.a.	3.1 (1991)
Total Sewage and Drainage, Solid Waste, Drinking Water, Air Quality	1,455.7	108.2
Environment-Related (estimated)	***72%***	***50%***

Notes:

Legislated programs:	Required by the Province of B.C. to conform to the Waste Management Act, Ministry goals for waste reduction and recycling and dam safety requirements.
Maintenance and replacement:	To maintain current levels of service and replacement of facilities that are reaching the end of their economic life.
Growth:	To provide basic systems to meet the needs of population and economic growth.
Board policies:	To (i) upgrade the quality of sewerage and drainage discharge to improve environmental conditions in local receiving waters, (ii) meet the Regional District's Solid Waste Management Plan that provides for expanded recycling, an energy-from-wasteplant and integrated recycling-transfer stations, and (iii) improve quality of water according to the District's Water Quality Improvement Program.
Committed Projects:	Projects that have already received Board approval to proceed.

Source: Greater Vancouver Regional District (1991).

Not included in the GVRD estimates or the Green Plan are what may constitute much more profound infrastructure needs: remodelling our infrastructure heritage to adapt to global environmental threats such as depletion of the ozone layer or global warming. In the case of sea level rises caused by climate change, for example, flood control infrastructure may require major modifications to handle significantly different flood and streamflow patterns. The threat of sun exposure under a compromised ozone layer may necessitate a shift to indoor -- or at least protected -- activities, with consequences for building/city/community facility designs. Costs of such changes have not been estimated, but could be significant.

Prosperity Linkages

The linkages between new "environmental" infrastructure requirements and prosperity are complex, encompassing complementarities, tensions and relationships of unknown character. The basic complementarity is likely to arise from benefits generated by the provision of these new infrastructure components. These benefits encompass (but are not limited to):

- improved health and productivity of the labour force;
- improved quality of inputs for production (e.g., water quality in food processing); and
- enhanced natural resource productivity (e.g., mitigation or avoidance of ozone impacts on agricultural production).

These positive feedbacks from environmental protection to productive efficiency underlie the basic concept of sustainability. However, the magnitude of the benefits are unknown and their distribution (relative to costs) are even less certain.

On a more concrete level, expanded "environmental utilities" could reduce the direct private cost of compliance with environmental regulations through economies of scale and distribution of costs across a broad set of beneficiaries. For example, technology, economies of scale and management structures may indicate that hazardous waste facilities should be developed and operated as a public facility, with cost savings feeding back to facility users.

Opportunities for the environmental protection industry to develop water, sewer, waste and monitoring infrastructure products and services for both the domestic and export markets, as noted above, could also be significant. For example, members of the environmental protection industry in Ontario average annual rates of growth of 17%, with current sales in excess of $2 billion; sales by B.C. companies exceed $100 million (ISTC, 1990). The United States represents a huge market for environmental utilities, with recycling markets expected to grow at 13% per year through to 1994, total public spending on solid waste disposal estimated at $7 billion per year (compared with the Canadian analog of $600 million), and municipal wastewater treatment and potable water treatment capital expenditures totalling $2.8 billion in 1995 and $4 billion annually, respectively (ISTC, 1990).

A basic tension between prosperity and sustainability rests on a fear that new demands will increase costs and that the magnitude and distribution of those costs (or associated tax burdens)

will affect competitiveness. Financing infrastructure investments and operations is, indeed, a major issue for municipalities and regional districts. A limited tax base coupled with pessimistic prospects of increased contributions from other levels of government narrow the sources of funding available for these investments.

There is, in fact, an emerging perception that prices charged for municipal infrastructure such as water and sewage/wastewater infrastructure are too low and that they do not fully cover the costs of new or replacement facilities, nor do they encourage the efficient use of the infrastructure or associated resource. Considerable work has been done in the area of water pricing, some of which has addressed water management from the perspective of sustainable development (i.e., it covers with both quantity (resource use) and quality (environmental protection) issues).

Three themes dominate this work. First, it is argued that the "user pay" principle should be applied to municipal infrastructure. The "user pay" principle dictates that the cost of infrastructure be borne through direct fees on users instead of indirect revenue generation mechanisms such as property taxes (which embody only a weak relationship between property values and water and sewer use).[7]

The second major theme in the literature addresses the structure of user fees, arguing that prices should be set at the long term marginal cost that, in the case of water, includes:

- the marginal opportunity cost of water;
- the marginal capital cost of infrastructure capacity; and
- the marginal cost of operating and maintaining the infrastructure (Pearse and Tate, 1990).

Prices that are set at less than marginal cost do not reflect the true resource costs of providing water services and encourage inefficient use of the resource and the infrastructure. Consistent with the marginal cost concept, prices should differ across water systems when any of the three elements above vary, and across time to reflect peak demand factors.

Furthermore, flat rate structures should be replaced by consumption-based pricing systems (e.g., meter use and volumetric charges). In contrast to consumption-based structures, flat rate fees effectively provide an unlimited supply of water for a given cost, thereby providing no incentive for resource conservation. A similar criticism holds for volume-based rates that either have a large first block (that effectively transforms the volume-based rate into a flat rate in the range of normal water usage) or volume-based rates with declining block rates (in which the per unit price of water falls as consumption increases). Flat rates or declining block rates are currently the dominant form of rate schedule for municipal, rural residential, and agricultural water

[7] Some argue that not all water and sewer costs need be covered by users because "the universal availability of convenient water supply, and the treatment of sewage, makes it possible for people to live a high-quality life in efficient urban agglomerations, which would not be possible without those services" (Apogee Research International Ltd., 1991). Such a "beneficiary pays" approach justifies some financing from a general tax base.

pricing. In addition, water taxes for both industry and agriculture are applied on a declining rate basis (e.g., British Columbia).

The third major theme in the literature is the incorporation of environmental costs in the pricing of infrastructure or infrastructure-related resource use. Although less well developed than the "user pay" concept discussed in the preceding paragraphs, it has been suggested that taxes could provide a vehicle by which sustainable levels of resource use (for example, water) that take into account local sensitivities of the environment could be incorporated into infrastructure costing (McNeill, 1991).

The requirement to finance new environment-related utilities and the adoption of pricing principles described above will affect the cost structure and operating decisions of economic players, as they are intended to do. However, it is difficult to determine *a priori* the overall impact on costs of production or the distribution of those impacts. Consequently, the nature and seriousness of the potential tension between prosperity and sustainability in the provision of new environmental utilities remains an open question.

The demands for environmental infrastructure have also raised questions regarding the compatibility of municipal responsibilities and the structure of the municipal tax base. This compatibility is being increasingly tested as municipalities are forced to respond to environmental policies (such as waste management prescriptions) developed by provincial and federal governments. In short, infrastructure investments that meet the needs of sustainability may require a revision of the allocation of tax revenues and planning processes to take into consideration capabilities and other issues of municipalities.

In evaluating this reallocation, experience in other countries may be instructive. In Sweden, for example, municipalities are responsible (required by national law) to develop comprehensive plans that take into account land base, physical infrastructure and social factors. These plans now also incorporate environmental considerations. Specifically, Swedish municipalities have the legislative power to introduce environmental standards based on local priorities and preferences. This power is supported by direct taxation mechanisms that broaden the municipal tax base beyond the property tax structure that typifies most Canadian municipalities (A. Kaarik, consultant pers. comm).

PHYSICAL INFRASTRUCTURE

SUMMARY

Physical infrastructure has long been recognized as a critical factor in economic development and prosperity. The preceding review suggests that Canada enjoys an extensive stock of transportation, energy and municipal infrastructure. However, the outlook for prosperity raises concerns related to the *maintenance and upgrade* of that stock. These concerns are most pronounced in the road transportation sector and at the municipal level.

Motivated by the concept of sustainability, additional demands will be placed on the physical infrastructure as its focus shifts from the efficient delivery of goods and people to efficiency *plus* fair access and minimal environmental impact. Combining environmental, social and economic factors generates a fairly complex set of principles for infrastructure planners. Those complexities embody both complementarities and tensions.

Opportunities for Joint Planning

Complementarities between prosperity and sustainability requirements present opportunities for joint planning. Some of the possible complementarities are:

- Management of urban traffic congestion;
- Implementation of energy efficiency measures in the residential, commercial, industrial sectors as well as infrastructure design and maintenance in the transportation sector;
- Development of "green" technologies in transportation, energy, and environmental monitoring and control for export to world-wide markets; and
- Decentralization of some decision-making and price setting to ensure cost-based pricing and incorporation of local demand patterns and environmental sensitivities.

Challenges to Joint Planning

However, the requirements of environmental sustainability and economic prosperity are not fully consistent. Policy-makers should recognize and attempt to resolve these tensions so that infrastructure planning does not support one initiative by compromising the other. Specific examples of tensions in the three segments of physical infrastructure discussed above include realignment of the relative role of road transportation and the allocation of the potential cost burden of additional municipal infrastructure.

At a broader level, the concept of full cost accounting that wraps environmental and social costs into prices could have significant economic impacts. Increases in prices, especially for important production inputs such as energy, will increase the overall costs of production and could compromise international competitiveness. The concomitant change in *relative* prices will also

impose costs as firms adjust their operations. The challenge to policy-makers will be the application of the full cost accounting concept -- defining the appropriate pace of application, the treatment of exports and imports, equity in applying the concept across industries, and consideration of income distribution impacts among different sectors of society.

Research and Development

Another challenge facing policy-makers in industry, labour and government is the management of R&D. A product of historical concern with economic competitiveness, the current pattern of R&D may not be fully consistent with the spirit of environmental sustainability. Shifting the focus of R&D will likely encounter resistance from established sectors and raise questions regarding appropriate roles for industry, government and academic institutions. However, R&D holds promise both for addressing domestic environmental concerns and for nurturing a competitive, export-oriented environmental protection industry.

PART B:

INFORMATION INFRASTRUCTURE

INFORMATION INFRASTRUCTURE

INTRODUCTION

Information infrastructure encompasses a vast array of goods and services, consisting of physical capital – ranging from satellites and communications grids to computers, telephones, and radios – as well as the specific information provided by these services. From a prosperity and sustainability perspective, information infrastructure has often been credited with improving economic well-being and providing social amenity; the historical environmental impacts of this infrastructure have often been presumed to be beneficial. However, key sustainability concerns revolve around social issues, future environmental impacts within the sector, and environmental sustainability complementarities and tensions acting through linkages with other forms of physical infrastructure.

CURRENT INFRASTRUCTURE AND INITIATIVES

Canada is internationally renowned for the quality of its communication and information technology (C&IT) and for providing access to innovative services to a large proportion of its population and businesses. Pioneering work at the turn of the century originated in Canada: Alexander Graham Bell invented the telephone in 1874; the first long distance call was made two years later; and Marconi was, in Newfoundland, at the receiving end of the first transatlantic radio signal. Canada established the first nation-wide telephone system in 1931, and the microwave system put into place in 1958 was – at the time – the largest network of its kind in the world. Entering the space age, Anik A1 became the world's first geostationary communications satellite put into service. Canada also was the first country, in 1973, to have a coast-to-coast digital network in place. Canada continues to pave the way in implementing new technologies such as fibre optics; a $500 million 7000 kilometre fibre optic network was completed on the Canadian mainland in 1990, and 1992 will see its extension to Newfoundland (Vision 2000, 1992).

Physical investments of the telecommunications industry have grown significantly. Total facility investments grew from $17.8 billion in 1979 to $40.3 billion in 1990 (Communications Canada, 1992d). It is estimated that new investments over the next decade will range from $50-$100 billion (Vision 2000, 1992).

Such continued progress and commitment has allowed Canadians to have access to a wide range of services which, one or two decades ago, were largely unheard of; automatic tellers, fax machines, cellular telephones, and the availability of 911 emergency services have become a normal part of the every day lives of Canadians. Canada boasts the most comprehensive phone service in the world, serving 98% of Canadian households; its cellular network is geographically the largest in the world, available to 80% of Canadians and currently having some 600,000 subscribers (Communications Canada, 1992c).

To meet the growing challenges of the expansion of the C&IT industry, and to maintain its historical momentum, there are a number of important initiatives currently underway in the areas of policy, legislation and institutions, and employment.

Policy

One of the most coherent and comprehensive long-term policy initiatives in Canada involves *Vision 2000 – Networking the Global Village* (Figure 5). Vision 2000 concentrates on the development and implementation of Advanced Personal Communications. Its focus is the end-user of the technologies: the individual. Vision 2000 forms a guiding strategy for a cooperative group of C&IT companies, government departments, academia and research organizations, including Communications Canada and most of the major regulated companies. Vision 2000 works as a forum for planning a coherent strategy, as well as a mechanism for

initiating R&D in areas that would be too risky or expensive for any one single organization or company. The general premise is that cooperation will accelerate implementation, implementation will lead to greater customer benefits, and these in turn lead to market expansion in all sectors: computing, broadcast media, and telecommunications.

Canada is also active at the global level, both at working on setting global standards to ensure compatibility, as well as at negotiating international protocols and agreements for the use of telecommunications. For example, 1992 will witness a new international allocation of the radio spectrum to provide more efficient use of radio frequencies.

New Legislation and Institutions

The last two years have seen the rationalization and updating of a number of major pieces of legislation. In 1991, the *Broadcasting Act* was rewritten to set out more clearly the role of the Canadian Radio-television and Telecommunications Commission (CRTC) and, more ambitiously, to make the legislation "technology neutral" so that the CRTC is given greater discretion in regulating the industry during periods of rapid technological change. Also, the new *Telecommunications Act* (introduced in February 1992) underscores the principle of providing: (i) a coherent policy for the country as a whole under one regulatory agency; and (ii) a more flexible regulatory approach. The Act will allow the CRTC to refrain from regulating the industry where competitive forces appear to be adequate for meeting the public interest (of fairly priced, readily accessible services), while allowing the CRTC a central role in regulating common standards or in protecting the public from the abuse of information and invasion of privacy. In response to legislation and other initiatives, major institutions are undergoing restructuring.[8]

Work at Home Programs

Many private corporations in Canada have adopted 'Work at Home' programs to allow their employees to take advantage of C&IT services, while reducing company costs and improving general working conditions. At the Federal level, the Treasury Board is investigating the adoption of a Work at Home program to improve employee productivity and decrease government expenditures.

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[8] Telecom Canada renewed its alliance of cross-Canada telephone companies in early 1992, renaming itself Stentor Canadian Network Management. It jointly owns two new companies: Stentor Research will consolidate all R&D efforts of its member companies by 1993, and Stentor Telecom Policy Inc. will act as a government relations advisory arm. Communications Canada is also undergoing reform to improve its contribution to R&D; in April 1992, the Communications Research Centre became a separate Research Institute, with a mandate to develop telecommunications policies, regulations and standards (Communications Canada, 1992d).

PROSPERITY ISSUES

The major economic prosperity concerns currently facing the C&IT industry are:

- assimilating new media and technologies in all aspects of economic production;
- maintaining Canada's growth prospects in the sector;
- maintaining R&D performance; and,
- pace of industrial deregulation.

New Media and Technologies

The 'information' industry has historically consisted of three discrete areas: the broadcasting and motion picture industry; the print and publishing industry; and the computer industry (Brand, 1987). With the advent of technological changes within these industries, the overlaps are becoming more significant. In a few more decades, such distinctions may well disappear altogether. Three relatively new media -- electronic publishing, telematics, and transactional media -- provide cases in point.

Newspapers have relied on telecommunications for 140 years to gather news into editorial offices. But electronic publishing now involves increased use of telecommunications to distribute final copy from publishing centres to widely dispersed printing plants or to home video-display units.[9] Telecommunication carriers are also entering the publishing business: constructing, storing and editing messages, rather than just transmitting them. Electronic bulletin boards, such as iNet, Envoy 100, and Dialcom are manifestations of this trend.

The telematics industry (or computer/communications industry) is a merging of two industries because computing power is becoming more distributed (through lower cost and smaller size processors), and because telecommunications networks are being converted to modes of operation that, essentially, use the same modes of communication that computers use. One result of telematics is that systems are becoming 'smarter' and can be specifically customized; voice recognition computer software, for example, allows automation of directory assistance functions.

Transactional media involves more extensive use of video and graphic information. The original applications were oriented primarily to electronic publishing and information retrieval; current applications involve a broader integration of the fields of retailing, banking, marketing and consumer research. For example, all transactions which take place electronically (teleshopping,

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[9] The *Globe and Mail* encodes text diffused by satellite and stored electronically in computers for access over telephone lines: services such as *InfoGlobe* thus appear.

electronic banking in the home) will generate computer-based profiles of individuals and households which can be stored and used for computer market research.

There are many new technologies that are driving this change in how various media operate, but most are associated with a few key trends in the telecommunications and computing industries (BNR, 1991). The first trend involves a shift from *analog to digital* communication. The most ambitious projects in this area involve Integrated Services Digital Networks (ISDN) similar to the one just recently completed in Canada. With ISDN, any communications device -- telephone, television, facsimile machine, computer, etc. -- can be connected into this single network.[10] The second trend involves a shift from wired to wireless and fibre optic transmission. This key complementary component of the digital network is a rationalized shift away from the traditional wired connecting systems. Wireless systems are being used - for cellular phones, for example - to improve mobility and access in remote locations; satellite systems provide another example. In addition, however, a shift to fibre optics provides a low cost and efficient alternative to wired systems that were prone to interference and limited in their message handling capacity. The third trend involves advanced use of *Digital Signal Processing* (DSP). Increased computer processing speeds and lower costs have resulted in major breakthroughs that further enhance the use of digital techniques. The integration of DSP with communications systems allows customizing of intelligent networks.[11]

These new technologies have important implications for what is now technically feasible. Voice, data, and image can now be combined on one network; the Megaplan and Mach III services offered in Canada are examples. Mobile communications are less costly and will become more routine after 1994, when a satellite dedicated to mobile users will be placed into operation in Canada. Sonet Radio, being developed by Bell Northern Research, will introduce digital technology to mobile communications, improving both quality and capacity.

At a personal level, many of the new features being offered by telephone companies are a direct result of the conversion to digital systems; calling number display, bilingual voice recognition, three-way conference calls, message waiting, ring again, customer trace, call transfer, and voice mail are but a few examples of recent enhancements to POTS ("Plain Old Telephone Service"). In the United States, AT&T will, late in 1992, be accepting subscribers for its '700-number' program. The program assigns a personal number to an individual for life, and that number will follow that individual whether they are at home, in the office, or in their car; digital and

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[10] Telephone systems historically used analog techniques for transmitting voice or other messages over radio waves or copper wires. These techniques are - put simply - based on vibrations; much the same as a vibrating needle is used on phonograph records. Digital technology, on the other hand, operates in discrete pulses or steps; an example is typical computer processing that processes all information as a series of 'ones' and 'zeroes'. Conversion of communications systems to digital operation allows a more direct interface to computers and, for significant efficiency increases, allows multiple messages to be sent on a single channel without interference.

[11] Data compression via DSP can speed up transmission by an order of magnitude, while other advanced techniques improve quality and clarity or provide new types of services. DSP is the backbone to high-definition television, character recognition, and voice and speech recognition.

wireless technology makes this possible. In Canada, in June 1992, a desktop computer-based video-conferencing system ("VISIT") was introduced.

Globally, the trend is to more establishment of networks. A 'network economy' is one in which individual cities and regions are interconnected by telecommunications highways for the exchange of voice, data, facsimile and video messages. The role of telecommunications has been to speed up the diffusion of computer power through resource sharing. Intra-corporate computer networks have developed wherein power is centrally located but made available to remote locations via terminals and channels of digital communication.

At the level of the workplace, networking is also evolving rapidly. The current direction in the evolution of computer networking is towards office, factory and warehouse automation in which local area networks (LANS) are used. The interconnection with LANS and wide area networks (WANS) provides organizations with hierarchical systems for managing, controlling and integrating their dispersed and diverse functions. Inter-organization consistency is being achieved by the adoption of open systems interconnection (OSI) standards by manufacturers of computer equipment. An example of this is the cooperation of banks and retailers in electronic funds transfer at point of sale.

Growth Prospects

Many analysts expect that the international C&IT industry will be one of the largest in the world within the next decade. Current global markets for communication services are approximately $400 billion annually; equipment sales generate an estimated additional $100 billion in sales annually. In Canada alone, capital investment in the industry approaches $6 billion. Canadian sales of communication services, equipment, and information technology are about $36 billion and the industry employs some 300,000 people. Growth in the industry has far surpassed that of most other sectors of the Canadian economy (Communications Canada, 1992c).

A key economic challenge over the next decade will be for Canada to maintain its current international position in this industry. There are signs that its historically favourable position is in jeopardy. Although the domestic market growth has been buoyant -- real growth has been about 7% annually -- it lags behind typical global growth rates that exceed 10%. Also, Canada has recently shifted into a net import situation for telecommunications products; a net balance of trade surplus of $800 million in 1982 deteriorated to a $200 million deficit in 1990 (Communications Canada, 1992c).

R&D Performance

The role of R&D in promoting technological changes has been substantial but Canada has recently been lagging its major trading partners in R&D efforts. The telecommunications industry is the largest performer of industrial R&D in Canada (14% of total R&D in 1990), yet it still represents only 0.16% of total Canadian GDP (Communications Canada, 1992c). The United States, Japan, Germany, France, and the United Kingdom all spend in excess of 0.25% of their GDP on telecommunications R&D. Changes in the regulatory structure and organization

of the Canadian industry are expected to increase R&D performance, but it is likely that massive injections from both the public and private sectors will need to persist to match efforts in other countries.

Deregulation

The new Canadian legislative framework involves a shift from regulated monopoly to regulated competition. Within this legislation, however, the CRTC has been given fairly wide discretion in deciding when it should and should not regulate activity.[12] The issue of regulation is therefore likely to persist as an important policy variable over the next decades.

The changes in industrial structure are challenging some of the traditional monopoly positions, while also creating potential new niches for new services. A key tension is whether some monopoly elements should be maintained in the industry. Some argue, for example, that certain activities -- such as overseas calling -- should be handled through a single public company with monopoly rights to such an activity. Others argue for open entry, allowing smaller private companies to get involved with various types of specialized carriage service. A concern is, for example, that some type of cross-subsidization is still required to provide universal access to telecommunications services; this cross-subsidization is available only with some form of monopoly control. Open entry would cause smaller firms to commence "profit-skimming" from the larger firm on the lucrative end of the business, thus causing the less lucrative (but perhaps socially and politically important) part of the business to be placed in jeopardy. A corollary can be made with the deregulation of the airline industry: upon deregulation, smaller communities lost services to which they had become accustomed.

A related tension involves the entrenchment of existing markets. Cable television, for example, has traditionally operated as a stand-alone regulated monopoly. The barriers to entry for new firms were quite obvious: massive investments would be required to duplicate the cable television system into any given neighbourhood or household. New technology effectively tears down these barriers; television and video signals could readily be transmitted on the same network as voice telephone or data transmission, at a very low incremental cost. While there are clear advantages to the final customer to such a move, the industrial benefits might be mixed. Concentrating all types of media (video, data, voice) under the control of one firm might itself lead to monopolistic inefficiencies.

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[12] The new legislation was a response to the increased globalization of the industry, decentralization of activity, and merging of many of the technologies. In addition, the legislation was intended to rationalize a number of regulatory tasks under a single agency. This was largely a response to a landmark Supreme Court decision (respecting AGT) in 1989 that even provincially-based, investor-owned companies fell under Federal regulatory jurisdiction. Current telecommunication industry structure involves two national companies in the carriage sector (Unitel and Stentor), 49 independents, and Teleglobe, which has a monopoly on overseas services. The CRTC regulates rates, to ensure fair pricing, and standards (such as through the Terminal Attachment Program) to ensure the compatibility of services. The CRTC is expected to use "forbearance and discretion" to decide whether a particular sector (such as cellular telephones) is operating in a manner that is consistent with the public interest. In general, however, the intent is to allow increased competition; an example of this is that the CRTC is allowing greater liberalization through resale and sharing of services.

Complicating these tensions are two other economic realities. First, Canadian industry is subject to intense global competition. Are larger 'monopoly-style' firms with a secure domestic foothold going to compete better globally, or are smaller firms better able to react to a rapidly changing global market? Second, the fast pace of technological change is causing product life cycles to become shorter. Monopolies have traditionally been associated with long-lasting 'reliable' products that underwent very little change; experience elsewhere has shown that deregulation increased industrial R&D and technical innovation. Are smaller firms thus perhaps better placed to move the industry forward? Debates on these questions persist, both inside and outside the industry, and few incontrovertible answers are available.[13]

[13] One of the oldest rationales for promoting regulation was when an industry had the characteristics of a 'natural monopoly'. Its primary attribute were declining average costs over all relevant levels of activity; in the absence of regulation, buyers would be gouged by the firm through high prices and no amount of competition could change this because the industry's cost structure provided a natural barrier to entry. Available evidence suggests that, in the telecommunications industry, such cost structures exist *only* at a very localized level (within a small distribution area, for example) and that, at the scale of most company operations, long-run anti-competitive pricing is not a concern. The 'natural monopoly' argument is thus no longer regarded as a valid basis for promoting regulation of the Canadian industry (Babe, 1990).

SOCIAL SUSTAINABILITY

COMPLEMENTARITIES AND TENSIONS

The major social sustainability issues facing the C&IT industry are:

- whether there is some basic level of service to which everyone should have access;
- worker freedom and potential exploitation; and
- censorship.

Universal Access and Pricing

A key tension is whether some minimal level of service and some minimal level of access to information should be guarantied to every Canadian, regardless of income level or location. From a moral stand-point, freedom of access has often been regarded as a fundamental human right which, if not upheld, could lead to exploitation of those individuals or groups not having access to key information. From the perspective of economic productivity, information is a factor of production that will improve the economic performance of individuals, organizations and society as a whole. Further, the idea of equitable access to information infrastructure is often regarded as a fundamental policy goal in Canada; the July 1987 Telecommunications Policy Framework for Canada asserts that a key policy objective is to "maintain a universally accessible and affordable telephone service" (Communications Canada, 1987). By contrast, however, it is clear that *limiting* access -- to protect individual privacy or corporate interests -- can also be a prerequisite for social, economic and political stability.

Product and information price is closely tied into the access issue. Economists regard information as a 'free and public good' because it is something that can, in principle, be shared without hindering anyone else's access to it. Some argue that all information media -- newspapers, public databases, television, radio -- should in principle be free to the end-user and that, if funding is necessary, it should be publicly funded the same way that roads and highways are publicly funded. This leads to greater universality and free access to information.[14] In such a case, businesses might becoming more competitive due to lower information costs, and there might be improved well-being from increased leisure time enjoyment. The greatest threat to prosperity, however, is that such a move might place a tremendous fiscal drag on the economy, as some of the infrastructure would need to be publicly funded. Alternately, if it were not completely funded, the industry itself might not have the required revenues to meet on-going costs and maintain R&D at levels required to maintain technological competitiveness.

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[14] In Singapore, for example, a National Information Infrastructure strategy has a goal to place a minimum level of service in every household by the turn of the century. Japan has set a target of having fibre in every home by 2015.

Others argue that information has a cost associated with its generation and delivery, and that end-users should be made to pay for that cost in relation to the value they derive from the information or the service. Bell Canada's proposed rate re-balancing, for example, involves removing historical cross-subsidization so that long-distance business users will no longer be subsidizing local household telephone service. A user-pay approach would result in investments and services which can lead to greater economic productivity, and which would not impose a cost burden through any form of cross-subsidization. Infrastructure development would likely focus on business needs, and would, among other areas, require intensified focus on providing secure channels that protect proprietary interests. Economic efficiency might be achieved through providing improved services at the lowest possible cost, funded privately. Public expenditures could be diverted to other needs, such as public transportation infrastructure or to social services. The greatest threat to sustainability might be that it undermines some of the principles of universal access to information and information media. Resolving such pricing issues forces a major re-examination of some of the principles of access to information and access to information infrastructure.[15]

Job Quality

There is little doubt that the combined impacts of decentralization and merging technologies are creating entirely new work modes. 'Tele-working' -- the mediation of work tasks through computer networks -- is becoming more common. Conversely, worker preferences for these types of work modes is itself creating a demand for new technologies that further enhance the work. New technology and decentralized work modes are thus co-evolving rapidly. Although this trend on the surface appears to be generally beneficial, a key issue is whether these changes will indeed improve job quality.

There are many complementary benefits from an increase in work freedom (Estabrooks and Lamarche, 1987; Reich, 1991). Worker productivity increases, primarily because workers can organize their schedules more flexibly. Customer satisfaction also increases, usually because customers have more freedom to schedule *their* use of the services being offered. Another potential benefit from this increased freedom is that it provides employment opportunities for some groups which, traditionally, were discriminated against because they were unable to be at the central workplace all of the time: the most notable examples of this are women who had chosen previously not to enter the work force. Other examples, however, include potential part-time workers such as students or those undergoing retraining.

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[15] It is important to distinguish between private and public components of information infrastructure. Use of the term 'public highways' is not altogether appropriate as an analogy for information infrastructure; 'private toll roads' would be a better description. Most corporate computer networks, for example, are well isolated and can be well protected from other users. It is quite likely that such 'private toll roads' will become more numerous: individual businesses can use their networks for secure video meetings; individual households can subscribe privately to their favourite electronic journals; buyers can purchase goods and services through electronic catalogues. In such a scenario, all of the services, carriage and the information itself, allow some form of 'exclusion'. Prices can be charged according to the value of the service to the end-user. Costs can be recovered through this mechanism but, if one believes in universal access, it is a given that some individuals might be excluded.

A serious potential tension, however, is that advanced technologies will increase worker exploitation. Recent attention has been drawn to the establishment of "tele-colonies" in the West Indies where low-paid female labour is used for data processing functions: information is moved via satellite to and from home offices in the United States. Although this is an extreme example of how globalization has given companies freedom to locate their activities wherever it is most profitable to do so, it raises key social concerns. Domestic labour may find that it is competing more directly with foreign labour in countries where labour standards are less stringent. Even within the domestic labour market, however, many unions and labour representatives have expressed concerns that workplace health and safety standards may decrease; current health and safety inspectors do not have the mandate to inspect home offices. Increased responsibility for home safety will thus be placed on the worker themselves. This, it would seem, generates training requirements which are not being addressed by available programs and institutions.

Another tension is that the changes will lead to 'bi-modalism' of the work force job structure. The idea is that rapid technological change will essentially eliminate much of the middle class, elevating them to high-tech jobs, while concurrently increasing the subjugation and marginalization of lower class workers. Although most evidence suggests that this has not been happening in the past[16] -- technological changes have allowed almost everybody to improve the general job quality -- there remains wide concern that some people will be left behind because of current organizational structures. Two examples of this involve older workers, not adapted to keeping up with technological changes in the workplace, and women who choose to take a break in their careers to raise families. A concern is that, in both of these cases, the worker will be marginalized: in one case because they are unwilling to work with new technologies and, in the other case, because a short absence from the work force would decrease the value of the worker's skills given the rapid changes taking place.

In summary, clear programs must be put into place to ensure that workers are not exploited as a result of their physical isolation from the traditional workplace. On-going training in safety standards and technological advances will become a more critical component of both employer and government training programs.

Censorship

Current globalization trends may require that we pay closer attention to information content. One example relates to criminal activities; the proliferation of private computer networks provides scope for clandestine activities that are less easily regulated and monitored than those over public broadcasts or in print media. Canada's pornography laws, for example, in principle apply to material transmitted over computer networks, although the capacity to monitor such

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[16] See Estabrooks and Lamarche (1987). A related issue is that employment opportunities in the 'information infrastructure' industry are regarded by some as being of higher quality than those in traditional physical infrastructure industries. An image of a seasonally employed unskilled road crew worker, juxtaposed next to a full-time computer analyst, comes to mind. But many will argue that such stereotypes are misleading and that alternate images – of computer key-punch operators and airline pilots – might lead one to conclude the opposite. Comparative job quality remains an open-ended debate.

material effectively is currently not available -- some would argue that it should not even be developed. Also, at one time, all overseas transmissions originating and terminating in Canada were required to be routed through a single earth station so that, if necessary, transmissions that might be a threat to national security could be monitored. Although such censorship is decreasing, it is clear that issues of information content have, at times, been instrumental in the design of the information infrastructure itself.

ENVIRONMENTAL SUSTAINABILITY ISSUES

COMPLEMENTARIES AND TENSIONS

As noted previously, there have been few historical concerns regarding the environmental impacts of the industry. This is primarily because the industry is usually credited with improving environmental quality because of its effects on overall economic efficiency. There are, however, a number of environmental sustainability issues facing the C&IT industry:

- role of environmental information collection and dissemination;
- industry adoption of good environmental operating practices;
- short product life cycles;
- use of rare raw materials for selected manufacturing processes; and
- declining costs that encourage material throughput.

It should be noted that the last three issues should not be regarded as environmental crises at this stage. What is critical, however, is that decision-makers realize that these issues exist and that, if they are not addressed, environmental problems might develop at some future date.

Environmental Information

A key policy question is whether public policy relating to information infrastructure should explicitly encourage the dissemination or collection of certain types of environmental information. One position encourages immediate and widespread dissemination of *currently available* information to assist developing regions and marginalized economic groups (Meadows, et al., 1992). It requires public policy to concentrate on establishing networks which allow currently available information to reach as many people as possible.

A second position asserts that the content of much of the currently available information is not adequate for decision-makers to come to coherent decisions regarding environmental sustainability (Victor, et al., 1991). There is a need to encourage immediate and widespread collection and analysis of *new types* of information which can be used to select appropriate actions. This might involve, for example, expanded incentives for the use of geographic information systems (GIS) in gathering, interpreting and displaying important economic, social and environmental information.

Good Environmental Operating Practices

A significant complementarity between economic prosperity and environmental sustainability is that, because of the C&IT industry's economic success, it has been able to afford investments in internal environmental "housekeeping measures". The environmental control costs (ECC) of the industry are lower than most industries and, coupled with its higher than average

profitability, there have been significant opportunities for meeting environmental regulatory standards.

For example, the ECC/Output ratio for all manufacturing firms in the US is approximately 0.54% and for heavy industrial firms ECC approaches or exceeds 3% of output value; ECC for the communications industry, however, is 0.39% of output value and ECC for the consumer electronics is generally less than 0.30% of output (United States Department of Commerce, 1988a, 1988b). This has allowed companies such as Northern Telecom to accelerate many of its regulatory compliance programs; it is expected to phase out CFCs in its production, for example, well in advance of national targets.

Short Product Life Cycles

Perhaps the single most significant environmental tension that exists within the industry is that related to the expectation that product life cycles will become shorter and shorter. There are numerous pressures that lead to shorter life cycles. Rapid technological changes accelerate product obsolescence. Industry deregulation provides incentives for firms to enter the market quickly -- at times with untested products[17] -- and creates an environment in which firms are continuously striving to make incremental improvements to existing products. The impacts of product obsolescence are familiar. It is estimated, for example, that there are about as many personal computers in the Canadian Federal public service as there are employees. Given that many employees have no reason or opportunity to use such computers, product proliferation has no doubt contributed to the fact that many computers are not being used.

The obvious solution to this problem is to design products which are upgradable. This is largely the approach which has been taken for the design of the major components of information infrastructure. Bell Northern, for example, has an "evergreening" approach to its product design which allows constant upgrading; the most notable case deals with its switching technologies which can be upgraded to faster technologies as they are developed (BNR, 1992). This same approach is less obvious, however, in the market for consumer end-products. In addition, where upgrade paths for equipment are available, consumers often reveal a preference for replacing products with new products rather than upgrading existing products.

Raw Material Inputs

One potential concern over the longer term is whether the raw material input requirements of the C&IT industry will accelerate the use of scarce goods for which there are no substitutes, or whether the use of certain types of materials will cause detrimental environmental impacts. A concern relating to resource scarcity and potential environmental problems is the use of plastics in consumer end-products. The industry is in a position to have a substantial influence on plastics use and on mitigating potential environmental impacts associated with plastics but, by and large, there have been few initiatives in this area. With respect to other material inputs, a

[17] This problem is especially endemic to the computer industry (Brand, 1987).

potential tension is that, with rapid advances in materials technology, the materials developed for electronic component design may have detrimental human or environmental health effects which are currently not known.

To date, these issues have not received a great deal of attention within the industry because some of the commonly used materials are relatively abundant (such as silicon for circuitry or quartz for fibre optic design) or, more recently, because some of the technological shifts have been less materials-intensive. An example of the latter is the move from copper-based wire systems to wireless or fibre-optic systems.

Declining Production Costs

Technological developments in information infrastructure have resulted in a higher level of many new types of services, as different media become more integrated and as automatic systems dealing with these media become more intelligent. Communications costs for private and public enterprises have also been dropping as a result of the greater capacity and lower cost of communications networks. Over the past two decades, telecommunication costs have declined on average by 11% per year (Communications Canada, 1992a). These declining costs have contributed both to the trends to shorter product life and to the general disregard for raw material input availability. They encourage a "throw away" attitude to product utilization.

As the trend in cost reduction is not expected to abate, waste generation potential by the C&IT industry and by consumer end-products can be expected to increase. Adjusting product prices to reflect potential environmental externalities, to encourage recycling and to discourage early abandonment of a product, is one potential means for promoting environmental sustainability while posing little threat to overall economic prosperity.

INFORMATION INFRASTRUCTURE

SUMMARY

The expanding role of information infrastructure is expected to contribute to increased prosperity through higher productivity, improved working conditions and a greater range of available services. Social sustainability will be improved through providing wider access to these services to a wider range of social groups, thus empowering many of them with the information and the technology for improving their own well-being.

There are, however, a number of critical tensions which have yet to be resolved. From an overall prosperity perspective, a key policy question is how quickly the C&IT industry should be deregulated. Rapid deregulation might improve industry efficiency and the type of services, although it might undermine social sustainability through threatening universal access. Further, accelerating the use of products with short life cycles increases total material throughput in society, thereby threatening environmental sustainability. On the other hand, persistent regulation and restriction of activity could dampen R&D effort, discourage foreign investment, and increase attempts to 'bypass' common carriers.[18]

From a social sustainability perspective, a significant tension involves job quality. Although new technologies and decentralized work modes will improve job opportunities, there is a growing concern that it will also lead to increased worker exploitation and a relaxation of health and safety standards in the home workplace. Training and education are key components of ensuring equitable treatment of workers.

From an environmental sustainability perspective, an area which is not being adequately addressed by most industry and government initiatives is that of the raw material requirements and waste generation within the C&IT industry. The assumption is generally that the industry can take credit for substantial waste reduction elsewhere, through improving overall productivity in the economy. What is being implicitly ignored, however, is that many of the industry's characteristics give it a natural proclivity for unsustainable practices. The three key areas of concern are: (i) the short product life and rapid obsolescence characteristic of rapid technological change; (ii) the use of rare non-renewable natural elements within the computer industry; and, (iii) rapid decreases in product prices and production costs which discourage recycling or material reclamation.

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[18] Bypass could occur through the introduction of private networks (although this is currently restricted to some degree because of restrictions on terrestrial rights of way and on satellite use) or through cross-border bypass. The latter might involve, for example, bypassing Canadian carriers by using deregulated systems in the United States.

At present there may be no obvious cause for alarm but, given the growth prospects of the industry, these concerns will become of greater significance and could, over the long term, undermine the sustainability of the industry. Addressing this challenge will require a greater concerted effort: (i) to enhance the availability of upgrade paths for all equipment; (ii) to reclaim or substitute the non-renewable materials; and, (iii) to provide explicit economic incentives to encourage recycling of equipment which can not be upgraded.

FIGURE 5
VISION 2000 - THE TARGET ENVIRONMENT

The Economic and Social Context in the Year 2000

- The quest for global competitive advantage will be the prime driver for private corporations in all industry sectors as well as for government economic policy makers.
- Knowledge-based innovation will be the key to the competitive advantage of companies and nations.
- Effective communications, in multi-media form, will play a strong role in the operating success of an enterprise.
- Product life cycles will continue to shorten. Time will be the strategic resource. Speed to market will determine competitive advantage.
- Hierarchies will be flattened and organizations restructured to facilitate innovation and market responsiveness. Networks will become prominent organizational structures.
- New skills will be required to generate knowledge-based innovation and to manage the transformed organizational structures of the 21st Century.
- There will be a skills shortage as our average population gets older. The education system will be overhauled. Training will become a top corporate priority. Immigrants, women, the handicapped and the young will increasingly be drawn into the work force to fill the skills shortage.
- The aging population will also create a crisis in health care. Preventive medicine and in-home care will be major health care priorities.
- The average family's two most important possessions -- cars and homes -- will become information and communications intensive products in order to support new lifestyles in work and leisure and help manage the natural environment more effectively. The entertainment industry will continue to flourish.

The Communications Industry in the Year 2000

- By the year 2000, the communications industry will be the mainstay of economic and social infrastructure in advanced societies.
- C&IT will be the biggest industry in the world, with growth rates expressed in multiples of the economy as a whole.
- The structure of the industry will be very different. There will be convergence of computer companies, carriers, cable operators, broadcasters, educators, publishers, entertainment and consumer electronics. There will be competition and collaboration between formerly distinct businesses.
- Mobile communications will be a major growth area. By the year 2000, 35% -- 50% of voice and data traffic will originate from mobile terminals (RF).
- Technology advances and convergence between carriers, cable, satellites and private networks will drive the integration of voice, text and data with image, high quality sound and video. Broadband ISDN services will be readily available by the year 2000.
- Greater intelligence in networks and terminals will permit the customization of service on an individual basis and give consumers greater control over the communications environment.
- Advanced personal communications systems will feature easy-to-use system interfaces (voice recognition and synthesis, touch input), natural language processing, and expert systems to seek out information.
- A personal numbering plan will be in place.
- Through a combination of these features, it will be possible to communicate directly with any person or information source, at any time, from any place.

Source: Don MacLean, MacLean & Associates in Vision 2000 (1992).

PART C:

LINKAGES BETWEEN PHYSICAL AND INFORMATION INFRASTRUCTURE

LINKAGES BETWEEN PHYSICAL & INFORMATION INFRASTRUCTURE

The previous two parts of this paper treated physical infrastructure and information infrastructure separately. Are there linkages between these two forms of infrastructure and, if so, what are they? This question forms the basis of many controversial and important debates in infrastructure planning. There is little doubt that if we have more people travelling or more goods being transported, we will likely need more physical transportation infrastructure. Similarly, it is tautological that the level of information infrastructure required will be proportional to the amount of services delivered. What is not clear, however, is whether information infrastructure and physical infrastructure are substitutes, or whether increases in one will lead eventually to increases in the other.

Role in Achieving Sustainability

The issue of linkages is particularly important from an environmental sustainability perspective. Information infrastructure, as noted previously, has often been assumed to be environmentally sound primarily because it removes pressures on physical infrastructure (as a substitute) or it allows more efficient operation of the physical infrastructure through introducing complex communications systems into the management of the physical infrastructure.

The formal empirical literature provides little guidance; information technology changes so rapidly that it is virtually impossible to measure the productivity of these systems in a consistent fashion over even a short period of time. For example, computers and communication systems have progressed so much over the past decade, that it is difficult to compare the technologies over this time frame.[19] It is just as difficult to detect whether, for example, people are using more or fewer communications services as a substitute for airline travel.

In many individual instances, however, we know them to be substitutes: business can be done over the phone or using videocom instead of in person; messages can be delivered electronically by facsimile instead of by hand courier. But we also know that, historically, the two types of infrastructure have developed in tandem. The origin of Canada's telecommunications network was founded by its two national railways; telegraph poles, railways and roads share similar development histories in most countries. Further, increased communications expands the desire and need for more transportation. Good global communication services now induce us to travel the globe, meeting clients or visiting holidays spots that formally did not enter into our sphere of experience. Globalization of trade through improved telecommunications, for example, has

[19] Examples of this are most pronounced in the literature dealing with patents. A chronic measurement problem that has persisted in the literature is determining what type of productivity increase should be attributed to any given type of technological improvement, when the technology does not 'stand still' long enough to provide a reliable benchmark (Kuznets, 1962; Rosenberg, 1974; Griliches, 1984).

increased the amount of physical trade in goods (Sussman and Lent, 1991). This increased trade places additional demands on physical infrastructure and on the environmental impacts associated with such infrastructure. In short, there might be some substitution between information and physical infrastructure for specific tasks, but, over the longer term, the two are likely to continue to grow in tandem, although probably at a different pace.

A key motivation to understanding the linkage between physical and information infrastructure relates to their final comparative impacts on sustainability. Important aspects of sustainability involve resource conservation and the reduction of environmental impacts generated by waste. Substitution of new information technologies and infrastructure for physical transportation infrastructure may *appear* to be sustainable in some respects: transportation uses more energy resources than communication; cars use more tons of steel than computers; new fibre optic cables use abundant material inputs (quartz) as opposed to less abundant materials used for highway construction (asphalt). It is fair to say, however, that to date little thought has been given to the environmental implications of such linkages and R&D has not been oriented to addressing these problems.

Taking Advantage of Complementarities

The major opportunities associated with improved information infrastructure will involve taking advantage of its identifiable complementarities with other forms of physical infrastructure. Some of these include:

- intelligent transportation systems;
- expanded reliance on tele-commuting;
- energy management systems; and,
- sustainable communities.

Transportation Systems: An example of a potential complementarity between transportation systems and information infrastructure involves the development of Intelligent Vehicle Highway Systems (IVHS). The basic idea of IVHS is that all vehicles on a given highway are placed under the control of a central computer-based system to improve both the safety and efficiency of traffic flow. An example of the development of an IVHS is currently underway in Calgary as a Vision 2000 demonstration project (Communications Canada, 1992a). The Mobile Vehicle Management System involves four companies which are pooling resources to research, develop and demonstrate vehicle location technology and software using cellular radio overlay techniques.

Energy Management Systems: Communication systems also can play an important role in many schemes intended for improving energy efficiency. The use of C&IT industry technological advances will allow improved energy management in new "SMART" houses, which have built in monitoring systems in every room to detect normal use patterns of the household and to manage energy use dynamically. Radio-controlled systems for controlling household power consumption have been in use for almost a decade by electrical utilities. They have been

particularly successful at reducing peak load demands and have thus increased overall energy efficiency and deferred the need to add hydroelectric or thermal capacity.

Tele-commuting, Infrastructure and Energy: A significant complementarity exists through the increased opportunities from tele-commuting. In addition to the potential benefits to workers, discussed earlier, it improves economic efficiency through higher utilization of existing physical infrastructure. Corporate costs generally decrease because tele-commuting allows corporations to use their existing physical investments at a higher capacity: downtown offices are less opulent because workers may spend less time there or, in many cases, will share those offices with co-workers. Physical infrastructure, therefore, is used more efficiently.

Examples of direct improvements from tele-commuting are numerous. One of the earlier studies (Hirst, 1973) illustrated that the relative energy consumption advantage of telecommuting over commuting -- representing the ratio of commuting energy consumption to telecommuting consumption -- was at least 29:1 when the private automobile is used, 11:1 when normally loaded mass transit is used, and 2:1 for 100% utilized mass transit. Hirst estimated that, in 1975, the United States import requirements for gasoline would have been eliminated had 12% of urban commuters switched to tele-commuting.

Sustainable Communities and Waste Reduction: A key concept in sustainable communities is integrating economic viability, social equity, and ecological health into all aspects of a community's activities (British Columbia Round Table, 1992b). The role of infrastructure in such a community would involve a greater integration of different components of both physical and information infrastructure. Communications are used to improve energy and transport efficiency and to decrease their environmental impacts. Information technology is used to monitor waste in a manner which allows one person's garbage to become someone else's input to a production process. Integrating information infrastructure into waste management systems, then, provides a coordination function that can reduce a community's net wastes. Materials management of this nature is already becoming an important component of recycling efforts. For example, standards being developed for the plastics industry envision using electronic bar codes (or similar markings) which will allow computer-assisted sorting of waste products. Such activities underline some of the potential complementarities which exist between environmental utilities and information infrastructure.

Summary

While there are many potential complementarities, a key challenge for decision-makers is not to fall into a trap that regards improved information infrastructure as a panacea. Although there are clear prosperity benefits, expansion of information infrastructure does have potentially adverse implications for both environmental and social sustainability -- either directly or through linkages to other types of infrastructure. Some argue that society in many ways has become mesmerized by the information revolution and that we are in effect caught up in a situation in which we believe that the social changes which are occurring are both desirable and inevitable (Babe, 1990). In fact, there are negative attributes to this information revolution. We do have opportunities to try to mitigate or prevent these impacts through developing sensible policies.

The main policy challenge will be to take advantage of beneficial linkages between information and physical infrastructure, and to minimize the instances where expansions in information infrastructure lead to a proliferation of environmentally unsound physical infrastructure. The following chapter explores some of the major themes of planning infrastructure for sustainability and prosperity.

PART D:

CONCLUSIONS

THEMES FOR INFRASTRUCTURE PLANNING

Past management of and investments in infrastructure have generally been characterized by centralized decision-making, funding from a generalized tax base, and limited incorporation of environmental costs. Continued dependence on these precepts is unlikely to lead to environmental sustainability. Furthermore, it may not support overall economic prosperity nor, in some instances, even be the most appropriate approach for the financial well-being of private sector players. The task before policy-makers, then, is to adjust the infrastructure planning framework to take into account changing needs and circumstances. In so doing, full advantage should be taken of potential complementarities that exist between environmental and social sustainability and economic prosperity, and conflicts should be avoided or mitigated.

The discussion in previous sections suggested specific areas where complementarities and tensions may exist. In this section, we take a step back from specific components of infrastructure to identify common themes and explore their implications for infrastructure planning and management.

Seven different themes are discussed. The first three fall into the general category of pricing; the last four cover decision-making and research and development.

Doing More for Less

"Doing more for less" captures changes that lead to better use of resources; it encompasses measures that allow the same (or better) service to be provided for less input of labour, capital, equipment or environmental resources. Energy efficiency and conservation initiatives such as demand side management activities, fall into this category as do recycling initiatives in waste managements and tele-commuting.

"Doing more for less" offers opportunities that con contribute to *both* prosperity and environmental sustainability. In the energy example, various reports document the existence of projects that can reduce energy requirements *and* save money (i.e., reduce costs). From an environmental perspective, conservation reduces depletion of non-renewable resources and eliminates waste emissions that are linked to resource use.[20]

Getting Economic Signals Right

"Getting economic signals right" requires that infrastructure users face appropriate prices -- prices that correctly reflect the resource cost to society of that infrastructure (or the service it

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[20] Although "doing more with less" generally represents a complementarity between prosperity and sustainability, certain industries may experience slower growth as a result of dampened demand. In the energy example, significant energy conservation would reduce the demand for petroleum, natural gas, etc., with obvious effects on those energy-producing industries.

provides). Water services, as noted above, are provided at a price well below the value of the resource and service; and electricity rates historically have been based on average costs of existing generating capacity rather than the cost of new sources of power. Underpricing infrastructure services results in overuse (over-consumption) instead of conservation.

"Getting economic signals right" is consistent with a broad interpretation of prosperity that encompasses economic well-being at a societal level. The right signals encourage the most efficient mix of resource use and generate aggregate economic benefits. However, adjustments in prices -- moving away from average to marginal cost pricing or from general tax base financing -- could affect the competitiveness of individual players. Full pricing of road services, for example, could have significant impacts on the cost structure of companies in the trucking industry. On the other hand, it may also encourage a greater role for rail and intermodal transportation resulting in reduced urban traffic congestion, energy conservation, lower transportation atmospheric emissions, and a lower rate of consumption of farmland for road infrastructure.

In short, "getting economic signals right" is complementary to both environmental sustainability and a broad interpretation of prosperity, but could conflict with a narrower definition of "competitiveness" of individual economic players.

Incorporating Environmental Costs

One of the main principles of sustainable development is full cost accounting -- incorporating all economic, social and environmental costs into the price of a good or service. If operationalized, full cost accounting would likely have profound effects on current prices. First, it would raise the cost of most items; secondly, prices changes would vary, leading to a realignment of relative prices.

For example, full cost accounting would increase the price of most energy types; however, prices of coal and petroleum products could increase more steeply than (say) hydro-generated electric power. From an environmental perspective, the signals would encourage energy consumers to move towards more environmentally benign sources, with concomitant environmental improvements. Incorporating environmental costs would also encourage research and development in clean energies and new "green" export products and services.

However, full cost accounting is likely to raise significant tensions with prosperity imperatives. If the move to full cost accounting in the energy field encompasses direct and embedded energy exports,[21] higher prices for traditional energy sources could affect the cost-competitiveness of Canada's energy sector and other major (energy-intensive) exports.

Decentralized Decision-Making

[21] Embedded energy exports refers to the exports of goods and services that have a high energy content.

In both the energy (electricity) and transportation sectors, the value of centralized decision-making has been questioned. Doubts include the inability of centralized systems to take into account local needs, circumstances and environmental sensitivities in infrastructure investment, operating, or pricing decisions. Advocates of decentralized systems also place trust in "the discipline of the market" to ensure efficient allocation of resources. Some recent changes, such as the devolution of airport management and methods for setting runway charges, suggest that the decentralization approach is being adopted.

On the other hand, centralized decision-making can play an important role in infrastructure planning and management. For example, centralized systems can:

- set technological and pricing standards for road pricing, thereby facilitating its implementation;
- coordinate planning and delivery of land use and physical infrastructure in major metropolitan areas that cover a number of individual municipal jurisdictions;
- develop national environmental standards for various types of transportation vehicles, energy efficiency, etc.

The theme for sustainability, then, is not an uncompromised shift to decentralized decision-making, but a sensitivity to the appropriateness of the level -- or mix of levels -- of decision-making for different situations and issues.

The Role of the Private Sector

Although critical to economic, environmental and social needs of society, the challenges to maintaining and upgrading infrastructure for sustainability and prosperity are significant. These challenges are highlighted by our traditional approach to the provision of infrastructure -- namely, through the public sector -- and the financing of those investments -- namely, through debt financing by governments. In the current context of constrained fiscal resources and keen competition for scarce public funds (for environmental protection, social programs, public debt charges, etc.) infrastructure requirements may seem overwhelming.

In the energy and environmental utilities sectors, private sector participation has been forwarded as one possible approach to mitigating these constraints. Europe and the United States have a history of private sector participation (in terms of expertise and resources) to address public sector needs, especially in the area of water and wastewater services. Private sector participation in Canada is still relatively limited, although examples and new efforts are evolving. One of the themes for infrastructure planning, then, is to more fully explore public/private cooperation to reap the benefits of private sector involvement, namely: reduced costs, rapid project completion, guaranteed performance and preservation of jobs (Hyde, 1992).

A corollary issue -- the level of regulation -- exists for information infrastructure. In this case the pace of deregulation could affect industry efficiency and the type of services available; however, deregulation may also undermine social sustainability by threatening universal access to information infrastructure.

Public Involvement in Decision-Making

Another common theme in much of the work of the provincial and national Round Tables has been public involvement. From a sustainability perspective, public involvement provides a mechanism through which local social concerns can be voiced and opportunities for creative solutions exploited. Public involvement does, however, impose costs: direct costs of consultation as well as the expenses of the "infrastructure" of public involvement and empowerment -- the development of an information and knowledge base for all participants.

Public involvement through such processes (e.g., the federal Environmental Impact Assessment, Ontario's Environmental Assessment Act) also imposes indirect costs related to delays in planning and delivery decisions. Costs of delay not only result from actual use time and resources, but also from *ad hoc*, "crisis" management measures necessary to meet interim needs. Examples currently exist in both public transportation and waste management in the Greater Toronto area.

The economic impact of more extensive public involvement in consultation and decision-making is not clear. In some respects, public involvement could yield better decisions through more comprehensive "vetting" of impacts and solutions, and by the act of collecting important data on possible impacts. Better decisions could thereby generate long-lasting economic benefits. Yet the extent to which these benefits would outweigh short-term costs, and the overall impact on prosperity, is not clear and mechanisms to minimize the costs of public involvement and review processes must be continually explored.

Research and Development

The role of research and development has been raised throughout the previous three sections. R&D could hold the answer to many environmental problems. The Ontario Round Table, for example, indicates that the promise of export opportunities for environmentally friendly transportation equipment sector is bright; as are opportunities for clean coal technologies and environmental monitoring techniques. Indeed, environmental R&D may embody the strongest complementarity between prosperity and sustainability.

However, as indicated in the discussion on energy, the potential role of R&D does raise policy questions related to the appropriateness of Canada's current R&D resources and endeavours. Many of these questions are generic to R&D management. Others are more specific to environmental technologies and long-term environmental and social sustainability. For example, what are appropriate linkages between the environmental protection industry and research activities in universities and institutions, and how can those linkages be enhanced? As noted elsewhere in this report, there also remain questions about the allocation of research funds to

sustainability versus production issues, such social aspects of developments in information infrastructure, alternative energy sources and other "clean technologies".

CONCLUSIONS

Traditionally, a strong physical infrastructure was seen as a determining factor in the economic efficiency and international competitiveness of a nation. As we enter the information age, development of an information infrastructure becomes equally important to Canada's participation in a knowledge-based, global economy. Within the economic paradigm, infrastructure issues revolve around the deficit in the physical infrastructure stock in the country and nurturing an appropriate and adequate information infrastructure.

Notwithstanding these issues, the characterization of infrastructure as a servant of economic prosperity is quickly becoming an historical artifact. Concerns for the global community and for future generations have added the new motivation of sustainability; the role of infrastructure is changing from one of a factor of *efficient* production to one of a factor of *sustainable* production. This shift adds important environmental and social dimensions.

What do these new dimensions mean for infrastructure design and investment? Implications permeate society. At the municipal level, environmental concerns are manifested in demands for significant new forms and levels of (for example) water and wastewater treatment, solid waste management, and air pollution control and monitoring infrastructure. Environmental concerns also call into question transportation systems and urban structures, and the dominant role of energy from non-renewable sources in Canada's economy. Development of an information infrastructure brings with it social concerns related to access, worker freedom and exploitation and censorship as well as environmental concerns stemming from short product lives, raw material inputs and declining production costs.

Yet infrastructure planners will, increasingly, have to grapple with these multiple objectives. This paper addresses the challenge by exploring the linkages between infrastructure, prosperity and sustainability and, in particular, complementarities and tensions between infrastructure requirements for prosperity and for sustainability.

Drawing on examples from both physical and information infrastructure, it is apparent that complementarities do exist. For example, tele-working offers opportunities to create a personalized work environment and schedule that can increase freedom and enhances quality of life; enhanced energy efficiency both in the generation of electricity and end use of different fuels (e.g., in buildings and transportation systems) can both reduce costs of production and environmental pressures; and growth of the environmental protection industry offers new employment and income opportunities.

However, the challenges to joint planning for prosperity and sustainability are real. For example, although tele-working may enhance quality of life for some, there is a danger that workplace health and safety standards may be compromised and workers exploited; in the area

of physical infrastructure, pricing issues could alter cost structures with implications for competitiveness.

These complementarities and tensions are not unique to infrastructure. Many themes for planning for sustainability, including:

- "doing more for less";
- "getting economic signals right";
- incorporating environmental costs;
- decentralized decision-making;
- the role of the private sector;
- public involvement; and
- research and development.

cut across sectors and provide an opportunity for infrastructure planners to both contribute to and learn from other "architects of sustainability".

However, infrastructure embodies additional dimensions of sustainability compared to some other sectors. Canada's stock of physical infrastructure is aging; replacement and maintenance investments are estimated at some $20 billion. At the same time, questions regarding the appropriate form Canada's information infrastructure remain and our understanding of the synergy between physical and information infrastructure is poor. In many respects, infrastructure planners are faced with an embarrassment of choices and issues. But infrastructure planners also face the significant challenge of finding the "right" path among these choices and issues. This paper has described some of those choices as a first step in defining that path by identifying potential complementarities and tensions between the two objectives. Identifying these linkages provides a basis by which planners can take advantage of complementarities and minimize instances where they can potentially conflict. However, much more consideration and research is needed to build guidelines for a sustainable infrastructure strategy.

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