INFRASTRUCTURE, SUSTAINABLE DEVELOPMENT & SOCIETY

by

Sadaf Siddiqui

Department of Civil Engineering and Applied Mechanics

McGill University

Montréal, Canada

May 1997

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Master of Engineering

0-612-44105-9

INFRASTRUCTURE, SUSTAINABLE DEVELOPMENT & SOCIETY

ABSTRACT

Infrastructure is the foundation and the basic framework which permits cities to function. However, there are significant infrastructure problems in North America. In cities across North America, the infrastructure is deteriorating. The efficiency of a community depends on the condition of its infrastructure. The health and welfare of the residents and the economy of a country requires an efficient and sound infrastructure. North America will not achieve prosperity if it allows its urban infrastructure to decay to the Developing World's levels.

Increased new sources of revenue need to be explored by political officials to pay for the cost of upgrading our infrastructure to an acceptable level. In addition, developing an effective management approach is a long-term way to handle a problem as large and as serious as our current infrastructure crisis. Current engineering and construction practices have proved to be detrimental to our environment and depletion of natural resources. The future role of civil engineers should be the prevention of any damage to our environment and natural resources, and this can be achieved by incorporating sustainability into the current engineering and construction practices.

Research and development reduces costs and improves a nation's quality of life and competitiveness. The level of effort and resources applied to infrastructure research and development falls short of current and future requirements. Therefore, a careful investment in research, development and technology transfer, is an essential part of a national infrastructure renewal strategy.

Civil engineers must recognize that the current and future infrastructure needs are great, and our past ways of dealing with them are inadequate. They have a very important role to play to achieve success in infrastructure rehabilitation by ensuring the provision of adequate number of skilled and trained people capable of evaluating conditions of urban infrastructure, identifying feasible and economical alternatives, and implementing them. This can only be achieved by emphasizing rehabilitation as opposed to new construction at universities which are bringing forth students that are narrowly focused and not equipped to facc the challenge of infrastructure renewal and its sustainable development.

Finally, civil engineers must realize that there is more to infrastructure than its design and construction. These very facilities that they help design have many social, economic, political, legal, managerial, financial, and environmental aspects, with which they should be familiar.

INFRASTRUCTURE, DÉVELOPPEMENT SOUTENABLE ET SOCIETÉ

RÉSUMÉ

L'infrastructure est la fondation et le pilier fondamental qui permet aux villes de fontionner. Cependant, il y a des problèmes considerables d'infrastructure en Amérique du Nord. Dans les villes á travers l'Amérique du Nord, l'infrastructure se déteriore. L'efficacité d'une communauté dépend de la condition de son infrastructure. La santé et le bien être des résidants et l'économie d'un pays exigent une infrastructure efficace et en bonne état. L'Amérique du Nord n'aura pas de properité si elle laisse son infrastructure urbaine se délabrer à des niveaux similaires que dans les pays en voie de développement.

De nouvelles sources de revenus doivent être explorées par les politiciens pour les dépenses nécessaires pour la réhabilitation de notre infrastructure à un niveau acceptable. En outre, le développement d'une méthode de gestion effective est la solution à long-terme pour répondre à un problème aussi serieux que celui de la crise de notre infrastructure actuelle. Les pratiques actuelles de conception et de construction ont eu des conséquences détrimentales pour notre environnement et ont contribué à l'anéantissement de nos ressources naturelles. Le rôle futur des ingénieurs en génie-civil serait la prévention de tout dommage à notre environnement et nos ressources naturelles, et ceci peut être accompli par l'inclusion de la soutenabilité dans les pratiques actuelles de conception et de construction.

La recherche et développement réduit les coûts et améliore la qualité de vie et la compétivité d'une nation. La niveau d'efforts et de ressources reservés pour la recherche et développement en infrastructure est bien inferieur aux exigences actuelles et du futur. Pour répondre à ces exigences, un investissement en recherche, développement et transfert de technologie, est une partie essentielle de la stratégie de renouvellement de l'infrastructure d'un pays.

Les ingénieurs en génie-civil doivent reconnaître que les besoins actuels et futurs en infrastructure sont importants et que nos méthodes précedentes de leur consideration sont inadequates. Ils ont un rôle important à jouer afin d'accomplir avec succès. La rehabilitation de l'infrastructure en s'assurant de la disponibilité d'un nombre adéquat de gens qualifiés et entraînés qui soient capables d'évaluer les conditions de l'infrastructure urbaine, identifier les alternatives faisables et économiques et leur implementation. Ceci peut seulement être accompli par l'insistance sur la rehabilitation au lien des nouvelles constructions aux universités dont les diplomés sont étroitement concentrés et pas bien equipés pour affronter le défi du renouveau de l'infrastructure et son développement soutenable.

Finalement, les ingenieurs en génie-civil doivent reconnaître qu'il y a plus à l'infrastructure que sa conception et construction. Ces mêmes installations qu'ils ont aidé à concevoir ont plusieurs autres aspects d'ordre social, politique, legal, patronal, financier, et environnemental avec lesquels ils doivent être familiers.

ACKNOWLEDGMENTS

I would like to sincerely thank Prof. Mirza (Professor, Civil Engineering) for his constant encouragement and valuable advice throughout my stay at McGill University, both as a undergraduate and graduate student. This thesis would not have been possible without his valuable input and significant assistance. I am very grateful to him for directing me in the right direction for the future, introducing me to the challenging fields of infrastructure engineering and sustainable development through the *Infrastructure & Society* course, and enabling me to pursue a fascinating multidisciplinary master's degree.

I would also like to thank my family for their encouragement and support throughout my education and for putting up with me during the write-up of this thesis. I would not have gotten through it without them. In addition I am grateful to the students of the 1996 *Infrastructure & Society* course (303-469A), of which I was a teaching assistant, whose intelligent and insightful discussions helped me get a wider look at the issues involved and formulate my ideas further. In addition, I am thankful to Dr. Lounis (Post-Doctoral Fellow, Civil Engineering) for translating my abstract into French, on such short notice.

I am grateful to Prof. Westley (Professor, Management) and Prof. Rice (Professor, Urban Planning & Civil Engineering), whose graduate courses, *Strategies for Sustainable Development*, and *Transportation and Land Development*, aided me considerably in exploring the various issues involved with sustainable development and incorporating them into my thesis. I am also grateful to Prof. Friedman (Director, Affordable Homes Program), with whom I worked as a research assistant, for introducing me to the field of infrastructure efficiency and design for affordable housing.

I am also thankful to Ms. Thompson, Mr. Blais and the Technical Committee of the Federation of Canadian Municipalities for their assistance and overall direction with the 1995 McGill/FCM Municipal Infrastructure Survey and its final report, which has been incorporated into this thesis.

Finally, I would like to acknowledge the following organizations, cited in the literature, whose work has been incorporated directly or indirectly in this thesis:

- Canada Mortgage and Housing Corporation (CMHC)
- Civil Engineering Research Foundation (CERF)
- Federation of Canadian Municipalities (FCM)
- National Research Council Canada (NRCC)
- National Science Foundation (NSF)
- World Engineering Partnership for Sustainable Development (WEPSD)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

Infrastructure systems are our public works and the physical facilities found in urban settings. Reliable transportation systems, clean water, and the safe disposal of wastes are the basic elements of a civilized society and a productive economy. Infrastructure development first became necessary due to the deplorable conditions in urban centers towards the end of the 19th century, after the industrial revolution. However, no systematic method for repair or replacement of these systems was put into place. At present, the useful life of these systems has been exceeded and their renovation and replacement cost is increasing at an alarming rate.

Engineering students and professionals, involved with infrastructure, need to be fully informed about the different facets of infrastructure and its sustainable development. This thesis is designed as a guide for those who are unaware of the infrastructure crisis and need to be educated about infrastructure and its impact on society. However, it is not meant to be an exhaustive presentation of all the issues pertaining to infrastructure. It will provide an overview of the different issues involved and demonstrate that there is more to infrastructure than planning and construction and that it has many environmental, managerial, financial, social, economic, political, and legal implications.

This research program has three basic objectives:

1. To assist with the process of educating undergraduate and graduate students by gathering together in a state-of-the-art report information available on the different facets of the infrastructure and its impact on society, respecting the basic principles of sustainable development.

2. To formulate a framework for future research and development activity by establishing the present state-of-the-art in the various related areas along with the research needs in each area.

3. Finally, it will attempt to answer the question, "Where do we go from here?" and try to define the current and future role of the civil engineer and civil engineering education, with respect to infrastructure and sustainable development.

2.0 INFRASTRUCTURE SYSTEMS

2.1 INTRODUCTION

Infrastructure is another word used to describe our public works and the physical facilities found in urban settings. The American Public Works Association (APWA) defined public works as the following (106):

> *"Public Works are the physical structures and facilities that are developed or acquired by public agencies to house governmental functions and provide water, power, waste disposal, transportation, and similar services to facilitate the achievement of common social and economic objectives."*

Infrastructure ensures a healthy and high standard of living. In addition it makes our lives more comfortable and convenient and supports jobs and growth climate. It consists of essentials such as:

- Highways, roads and bridges;
- Airports;
- Mass transit systems;
- Water supply systems;
- Wastewater treatment plants;
- Sewer systems; and
- Solid and hazardous waste management systems.

Infrastructure facilities became necessary towards the end of the 19th century after the industrial revolution, when living conditions changed drastically. At first, to improve the living conditions, there was a need to improve the public health conditions. This resulted in the development of sewers and water supply systems. These were followed by transportation systems, electric power and telephone networks.

These facilities were not planned in a coordinated fashion until well into the 20th century. Most of them were planned to last for 50 to 75 years with no systematic method for repair or replacement put into place. These systems were not designed with the facility for expansion and adaptation to changes in the social, economic and technological conditions. This has of course led to the current infrastructure crisis which will be discussed in the Chapter 4. This chapter briefly discusses some of the infrastructure systems found in urban areas.

2.2 TRANSPORTATION SYSTEMS

Transportation infrastructures are the vital networks that tie the inner and outer rings of metropolitan regions together and promote growth and prosperity of an urban region. The economic health of a developing region depends on the transportation system networks that are available to maintain the mobility of the work force, attract new businesses and residents and increase land development (195).

2.2.1 Streets

Streets are one of the most vital and important infrastructure systems needed to meet the basic human, social and economic needs of the population. They are the oldest form of our infrastructure that require the expertise of many different professionals such as (195):

• **Highway Engineer:**	Designs new streets and prepares reconstruction plans for existing streets to ensure that they stay in good condition and are able to carry the daily load of traffic.
• **Traffic Engineer:**	Is responsible for the smooth flow of traffic.
• **Electrical Engineer:**	Ensures that the streets are properly lit to provide safety for both the motorists and pedestrians.
• **Environmental Engineer and City Planner:**	Develop plans showing the relationship of streets to the rest of our environment. They ensure a balance between the different modes of transportation and that the traffic is kept at a reasonable level.

Streets are the basic elements of settlements, villages and cities. They connect to form large networks. Most streets are public and provide space for many other parts of the infrastructure, such as water and sewer lines, electricity, gas, telephone and cable television, in their own right-of-way above or below ground.

People use streets for several functions such as (195):

- Pedestrian transportation;
- Vehicular transportation;

- Places to walk and talk;
- Recreation and play; and
- Commercial activities.

A city street network is comprised of local, collector and arterial roads. Local roads are primarily one way residential streets connected to collectors. Arterial roads allow access to highways and are themselves accessed from a collector. The arterial roads provide high level of traffic movement. These roads differ from one another in their pavement widths, depths and quality. The different classes of streets are distinguished by the following other characteristics (195):

- Length;
- Travel speed,
- Access control;
- Spacing;
- Traffic volume;
- Traffic control;
- Points being linked; and
- The percentage of overall traffic being carried.

The components of a typical city street infrastructure and their respective roles are (45):

- **Fire Hydrant:** Conveniently located near the curb, they supply high pressurized water flow for extinguishing fires.
- **Hydro Pole Lines:** Located by the sidewalk and curb, these high voltage cables supported by poles provide easy access route for the electrical maintenance people.
- **Street Light:** They provide light for night visibility and security.
- **Curb:** A street and sidewalk divider that eases water drainage.
- **Sidewalk:** Located usually at both ends of the road, sidewalks provide a safe route for the pedestrians.
- **Street:** Located in the middle of the road cross section, it is a route for vehicle travel. Usually consists of two driving lanes opposed in traveling direction. A two lane street is at a lower grade than the sidewalk. The grade is highest at the center

line of the road. Typically, the pavement has a 2% slope from the center line towards the curb to allow for drainage.

- **Storm and Sanitary Sewers:** Located beneath the street, they collect water wastes from residential dwellings and storm water. The sewers divert the water back to the water filtration plants.
- **Catch Basins:** Periodically spaced along the curb, on the street side, they collect rain water draining from the sidewalk and street.
- **Pavement:** This is the surface of the street and consists of a bearing surface, base course, course sub-base, and a prepared sub-base. The cross section of the pavement is required to bear and distribute the wheel load to the soil foundation.
- **Lane Dividers:** These provide alignment for the driver and allow traffic to proceed in an orderly manner. They are in the form of white lines painted onto the surface of the pavement, or reflectors attached onto the surface of the pavement.

The design of streets depends on the density of the development. Low density developments with detached housing requires longer streets than a higher density development with clustered or row housing. Higher density also translates into a higher volume of traffic, which in turn requires more streets. In cases where there is a limited amount of land available for streets, other alternative methods of transportation have to found.

2.2.2 Bridges

A simple bridge is one that is supported at two points (195). Bridges are important to social and economic well-being of the community since they (45):

- Provide better living standards for the general population in its general neighborhood;
- Enable businesses to move goods from one place to another over an obstacle such as a river;
- Help a community grow;
- Connect people from one side of an obstacle to another;
- Are more convenient to use than a barge system;

- Enhance trade;
- Create jobs; and
- Attract tourists.

The main components of the bridges are (45):

- **Substructure:** The substructure or foundation of the bridge consist of the piers and abutments which carry the superimposed load of the superstructure to the underlying soil and rock.
- **Superstructure:** This portion of the bridge lies above the piers and the abutments. The most common types are concrete or steel girders, rigid frames, arches, prestressed concrete girders, steel trusses and steel suspensions.
- **Deck:** This is the floor system which distributes the dead load and live loads to the main members of stringers. The deck which caries the traffic, is classified by its method of construction and materials, such as concrete deck slab, steel grid, laminated timber deck or orthotropic steel plate deck.

A **suspension bridge** is one of the oldest bridge forms. It typically consists of two or four cables draped over the two towers some distance apart. The distance between the towers is called the main span. The cable ends are embedded in huge concrete and masonry blocks to resist the dead load of the bridge and the live load due to the traffic. Smaller wire cables, called suspenders, hang down from the main cables to support the roadway.

A **cable-stayed bridge** consists of one or two large towers and diagonal cables that emanate from the top of the tower or from intervals along the tower to support the roadway. The stays allow for the use of stiffer decks and combine the suspension design with a concrete deck. The advantages over a standard suspension bridge are the cost, and speed of construction since anchorages are not necessary and there are no massive cables.

There are several types of **movable bridges** across waterways. Swing bridges are supported on central piers and are rotated horizontally, on either a pivot or a turntable. They do not limit the height of a passing vessel, but restrict the horizontal clearance. Bascule or drawbridges are normally of the two-leaf type, where the leaves open around an axle, operated by a motor. Vertical lift bridges are useful when the horizontal clearance required is greater than the vertical. The entire span of the bridge is lifted by cables directly along the towers of the bridge.

A **truss bridge** consists of several members made of wood or metal joined together in a series of triangles. The live and dead loads are distributed such that no member takes a disproportionate share of the load. The type of trusses depends on the configuration of the triangles. Truss members are either in tension or compression.

The substructures of bridges consist of abutments and piers that distribute the loads to the ground below. Abutments are walls of reinforced concrete or masonry that support a bridge superstructure and approach roadway and retain the embankment. Piers are the intermediate supports for a multispan bridge, composed of steel reinforced concrete, and can be either walls or columns. The superstructure consists of elements supported by the abutments and piers. The bridge deck supports the live loads and passes it down to the floor system, which is normally made up of transverse floor beams and longitudinal beams supported by widely spaced floor beams (195).

2.2.3 Transit Systems

The various components of the transit system are (45):

- City buses;
- Trolleys;
- Trams;
- Cable cars; and
- Trains;

The public modes can include taxis or limousines and mass transit refers to the subway and metro systems with multi-car operations. Mass transit serves a densely populated area.

Rapid transit (45):

- Allows users to travel without driving;
- Helps reduce the number of vehicles on the road;
- Reduces the number of car accidents;
- Forms a collective link between the suburban areas and downtown;
- Reduces parking needs in the business district; and
- Reduces pollution and consumption of gasoline.

The various components of the rail/transit system are (195):

- **Right-of-Way:** This is a strip of land legally owned by the transportation facility, on which the system runs.
- **Roadbed:** The roadbed is the earth base on which rests the track superstructure.
- **Way Structures:** These refer to all structures on the right-of-way, such as bridges, viaducts, and tunnels.
- **Superstructures:** These are all the fixed physical components that directly support or guide rail or fixed vehicles.
- **Guideway:** The guideway for the rail system is the track and includes complex switches.
- **Control Centers:** These are major communications centers for operational and monitoring functions The centers control signal and switch settings.
- **Stations and Terminals:** These represent the contact points for the system, where connections are made with other modes of transportation or other transit services.
- **Station Platforms:** Station platforms are either developed with a central platform serving trains in both directions or on a lateral plan where each direction has its own separate platform.

The cost breakdown for public transit can be divided into five categories (195):

- Transportation, which includes the wages of all personnel, materials and equipment needed by the operating personnel;
- Permanent-way maintenance, which includes the cost of personnel and materials and equipment needed to maintain the tracks, power supply, and signals;
- Vehicle maintenance, which includes the cost of personnel, materials and equipment and buildings necessary for maintenance, repair, testing, and the cleaning of cars;
- Cost of electrical power; and
- General and administrative costs covering all indirect operating costs, management, legal, accounting, insurance, benefits, and the maintenance of buildings and grounds.

2.3 WASTE MANAGEMENT SYSTEMS

The objectives of waste management are the control of the generation of waste, collection, transfer, transport, storage, processing, and finally, its disposal. The collection, transfer, and transport of wastes are the most costly elements of any waste management system and must therefore be effectively optimized. Waste management places a heavy financial burden on municipalities which recover a large percentage of that cost by incorporating user fees into property taxes.

2.3.1 Solid Waste Management

Solid waste management includes the collection, transportation, treatment, and disposal of wastes and is a crucial element of the city's infrastructure. Solid wastes can be classified into the following categories (195):

- **Garbage:** Garbage consists of the waste generated by the preparation, cooking, and serving of food, and the handling, storage and sale of produce.
- **Rubbish:** Rubbish consists of items such as paper, cartons, boxes, barrels, tree branches, furniture, metal objects, tin cans, glass, crockery and minerals.
- **Ashes:** Ashes are the residues from the fires and incineration.
- **Street Refuse:** This includes sweepings, dirt, leaves, catch basin residue, abandoned cars and horticultural wastes.
- **Building Wastes:** These include materials left over from construction such as lumber and pipe, and other materials generated from the demolition of buildings or the repair of infrastructure.

The components of solid waste management systems are:

- **Waste Collection and Transportation:** This is a person and truck system which traverses the streets on a planned collection route, and then travels to either transfer stations, material recovery facilities, incinerators or landfills. These collection programs are often the most expensive component of the solid waste management system. Significant savings are incurred with a proper collection route design, minimizing travel time and distance.

- **Transfer Stations:** Due to the high transportation costs, it is often more economical to bring the waste from a local collection system to a transfer station. From here, larger amounts of waste can be transported for further processing or disposal. In populated areas, disposal facilities are usually located at long distances from the waste source, and thus the efficiency of waste hauling increases with the use of a transfer station.

- **Material Recovery Facilities:** In these facilities, recyclable materials are recovered for further processing. This recycling infrastructure is practically nonexistent, due to its high costs. The municipal solid waste is also prepared for use as fuel and as a feedstock for composting.

- **Municipal Composts:** Municipal composts are used for decomposing solid wastes into a stable, humus like product under controlled conditions which is used mainly as a soil conditioner. Composting can reduce 70% of the solid municipal waste, which would otherwise be landfilled.

- **Incinerators:** Incineration reduces 90% of the volume of solid waste and produces heat for recovery in the form of hot water, steam, and electricity. There are very high capital costs involved with incinerators.

- **Landfilling:** This is the least expensive method of waste disposal. However, the costs are increasing rapidly due to the lack of suitable sites. At a landfill site, the waste is received, inspected, and weighed. It is then tipped and pushed to a workface where it is spread and compacted in layers by bulldozers. This process is repeated until a daily cell is formed. At the end of the day, the refuse is covered with a layer of soil. When a cell is filled up, the operation is repeated. In order to insure proper protection of our environment, sanitary landfills must have a cover, liner, gas collection and leachate collection systems.

Within buildings, wastes are collected by means of **chutes**, hoists, or elevators. In high-rise offices, the waste is bagged on each floor and brought down to a loading dock by the elevator. Hospitals and high-rise apartment buildings generally use chutes to bring down wastes to a central service area on the lowest floor. Unmanned hoists are usually available in construction sites and factories.

Dumpsters are wheeled metal containers used on construction projects, commercial developments, institutions, and some multifamily residential applications. The waste is loaded on trucks by mechanical means. Trucks play a very important role in the transportation of solid waste and come in variety of sizes and shapes. The material is mechanically compacted within the truck to optimize carting capabilities.

Since most landfill sites are located on the outskirts of urbanized areas, it is desirable to provide transfer stations. The packer trucks are discharged at these locations and the waste reloaded in containers for the final long haul to the final destination.

For effective management of solid waste, it is desirable to separate the waste at the source. If most of the paper products are collected at the source, at least 50% of the management problem would be eliminated, and another 10% could be reduced through the recycling of glass products and cans.

Compaction is a common practice in many buildings. Waste comes down the chutes directly into the hoppers of compactors. A ram compresses the wastes into paper containers. The resulting package is easily handled for carting away.

Composting is the aerobic decomposition of organic wastes, such as paper, grass, leaves, and food wastes, to produce a humus like material. Microorganisms fueled by oxygen cause the organic material to heat and decay into a useful fertilizer and soil conditioner.

When designing residential subdivisions, it is important to plan for waste collection. The location of service and access roads is determined by such factors, as the cost of collection. Road patterns should be planned to accommodate collection vehicles.

Planning for the location of landfills is a difficult task. Landfills require large open spaces shielded from view. They need to be close enough to urban areas to avoid long trips, yet far enough to make their presence acceptable. In addition, roads leading to them should be able to sustain intensive traffic (195).

2.3.2 Hazardous Waste Management

Hazardous wastes are the by-products of industries, research laboratories and hospitals in our modern society. They are wastes that may cause or significantly contribute to serious illness or death, or that pose a substantial threat to human settlement or the environment when not managed properly. They can be in the form of solids, liquids and gases. Hazardous waste is produced by some of the following industries (45);

- Manufacturing;
- Textile;
- Pulp and paper;
- Aluminum smelters;
- Chemical plants;
- Oil and gas;
- Lumber yards of treated woods;
- Small businesses;
- Domestic;
- Hospitals;
- Municipal; and
- Automotive industry.

Materials that fall under the category of hazardous waste are (45):

- Used oils;
- Solvents;
- Halogenous and non-halogenous solvents;
- Cyanides and sulfur compounds;
- PCB's
- Laboratory wastes;
- Radioactive wastes;
- Strong acids and bases;
- Polymers;
- Medical wastes;
- Nuclear wastes; and
- Used tires.

The hazardous waste disposal system has a profound impact on the environment, and the social and economic well-being of the community. Ineffective management of a hazardous waste disposal system can lead to the following problems (45):

- **Environmental Problems:**
  - Pollution and contamination of the groundwater, lakes, rivers, soil and air;
  - Poisoning of humans through the food chain;
  - Poisoning of humans due to long-term exposure of waste; and
  - Fire or explosions.
- **Economic Problems:**
  - Reduction of the value of the property near the treatment and the disposal center;
  - Reduction or termination of residential developments;
  - Law suits and high medical insurance claims.
- **Social Problems:**
  - Creation of great fear and stress among the residents living near the disposal site;

Treatment methods consist of thermal destruction technologies which include all types of incineration such as liquid injection, rotary kilns, fluidized beds, and industrial boilers. The methods depend on whether the wastes are solid, liquid or sludge, and on the heating value of the material. Incineration is used for most municipal solid wastes to burn the material or for the purpose of utilizing the heat of combustion. Treatment technologies include a variety of chemical, biological, and physical processes that remove hazardous constituents from the wastewater or convert the waste into a less hazardous form.

One of the most effective hazardous waste management methods is the reduction of waste generation. Some of waste reduction strategies are (195):

- Waste segregation of small quantities of hazardous wastes with large quantities of normal wastes;
- Improvements in housekeeping, materials handling, and process monitoring to reduce the generation of hazardous waste;
- Raw material modifications to introduce fewer hazardous substances into the production processes;

- Recovery and recycling of hazardous waste constituents at the point of generation; and
- End-product substitution of products that require fewer hazardous constituents in the first place.

2.4 WATER AND WASTEWATER SYSTEMS

The water component of infrastructure systems includes facilities for water supply, wastewater management, flood control, stormwater, and control facilities such as dams, reservoirs, groundwater systems, waterways, and irrigation facilities. It is basically a very large and complex part of the infrastructure network (106).

2.4.1 Water Supply

The major uses of water are in irrigation, municipalities, and industries. In the United States, irrigation uses approximately 34.5% of all the water, while industry uses 54.5% and municipalities use the remaining 11%. Industrial uses include all industrial processes, as well as cooling of machinery. Municipal uses include potable water for drinking and cooking, water for cleaning and sanitation and finally fire protection. There are also recreational uses of water such as swimming, boating, and fishing.

The sources of water can be explained by the hydrological water cycle, which consists of evaporation, precipitation and runoff. Water evaporates from rivers, lakes, oceans and vegetation, and rises up to the atmosphere where it mixes with dust and gas in the clouds. It then returns back to the earth in the form of snow or rain and runs off to ponds and lakes, or soaks into the ground.

The different components of the water supply system are (45):

- **Source:** The main sources of water are lakes, rivers, oceans, reservoirs, groundwater (wells), and basins.
- **Pumps:** High lift and low lift pumps.
- **Treatment Plants:** Water has to be cleaned from all chemical, organic and any other toxic waste in it. Treatment plants reduce the incidence of waterborne diseases and assure water quality.
- **Open Channels and Pipelines:** These are used for the conveyance of large quantities of water for relatively long distances, between the

points of supply and demand.

- **Pipes and Mains:** In the distribution network, these accessories are designed to deliver the maximum hourly flow in a municipality.
- **Storage:** Storage is necessary in any municipal water supply system to meet the variable water demand, to provide fire protection, and meet the emergency needs. Reservoirs can be found at the surface, standpipes, or elevated tanks.
- **Meters:** Meters promote lower consumption of water by quantifying the amount of water consumed per residence.

The water distribution network consists of piping grids running beneath the streets. The branch mains are fed from two feeder mains to provide service in the event of one feeder main breaking down. Valves between branch mains are provided to facilitate repairs and new construction. Typically, water is pumped up to a storage tank at the top of the building and then flows by gravity to the various users. If a gravity system is not adequate due to the difference in elevations between the community and the reservoir, a water tower is provided at the highest elevation, and the water is then pumped to the tower and distributed by gravity from there. Figure 2.1 illustrates the configuration of an urban water supply system.

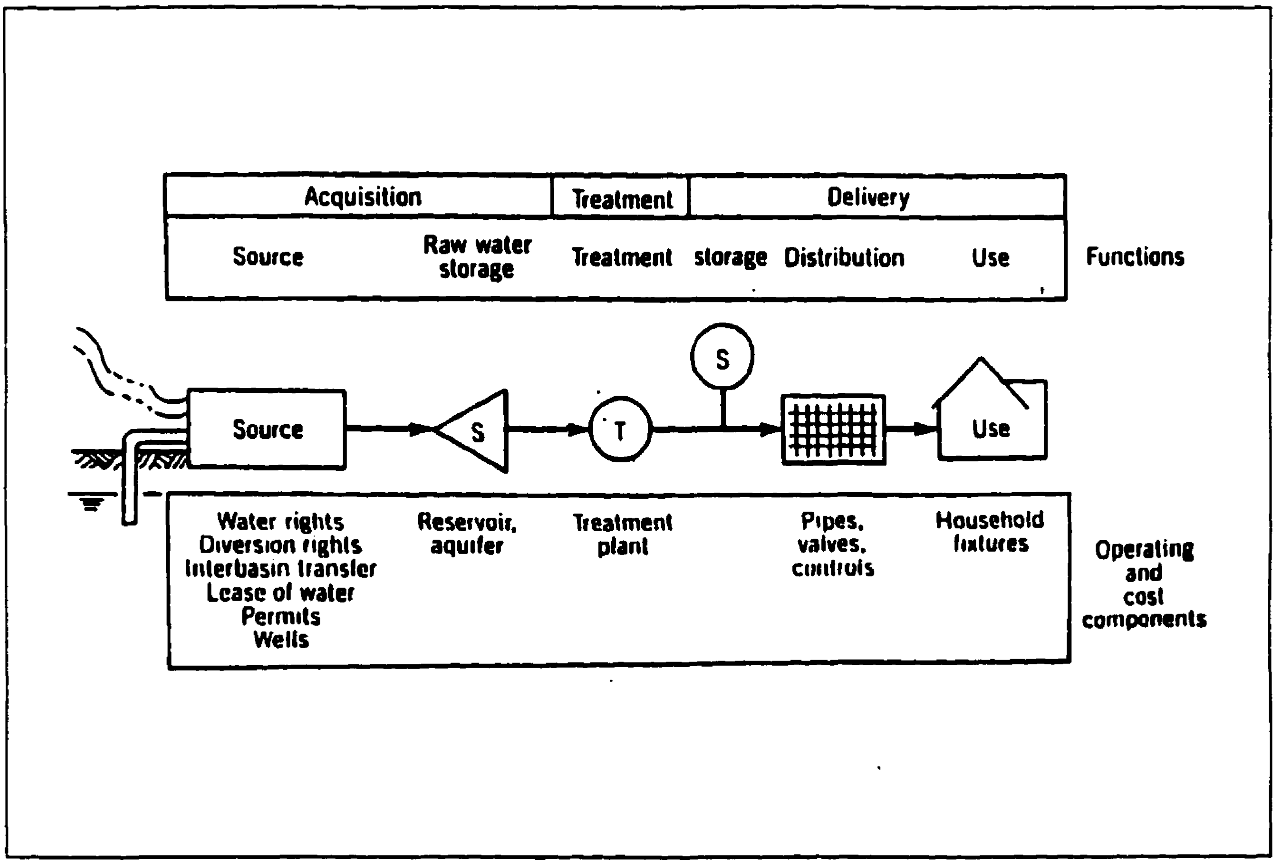


Figure 2.1 Configuration of an Urban Water Supply System (106)

The following factors contribute considerably to the consumption of water (195):

- **Climate:** People living in warmer climates take more showers.
- **Availability:** Water conservation strategies are more commonly found in communities facing water shortage.
- **Stage of Development:** Water consumption is much higher in industrialized nations.
- **Housing Density:** Greater open spaces require much more irrigation.

The lack of water limits human settlement and can seriously affect industry. For this reason, the planning and management of our water supply is very important. The water needs must be assessed on a continuous basis, new water supplies sought out, and the latest technologies applied. Preventive maintenance must also be planned and rehabilitation of older parts of the system must be regularly scheduled.

One of the most important aspects of the planning process is the conservation of the water supply. Regulations for water conservation can include water saving-fixtures, metering, denser settlement, and water saving landscaping. Communities that frequently face drought can use drought tolerant plants. One of the most effective methods of conserving water is the setting of water rates at the full cost of maintaining and improving an area's water supply system (195).

2.4.2 Storm Water Drainage System

Storm water drainage systems are essential to all urban and rural communities. Their function is the swift removal of runoff to eliminate or minimize inconveniences or disruption of activity and to prevent or minimize loss of life and damage to property resulting from flood related hazards.

The storm water runoff system is composed of both man-made and natural elements and includes elements designed primarily to obtain convenience at the initial phase of the system at the individual site during minor or frequent storms, and those elements which will provide the increased flow capacity necessary during an infrequent or major storm. These components are designed to provide safety and to minimize damage throughout the system, from the individual site to the drainage point of the drainage basin. Figure 2.2 illustrates the configuration of an urban stormwater system.

The components of a storm water drainage system are (45):

- **Permanent Storage Facilities:** These facilities consist of storage ponds, reservoirs, and stream channels that provide the maximum storage with the greatest amount of certainty. Provision of storage can reduce the peak runoff rates, aid in replenishing the water supply, and reduce the potential for downstream flooding, stream erosion and sedimentation.
- **Temporary Storage Facilities:** These facilities consist of parking lots, roof top ponding, golf courses and recreational parks and fields, where water can accumulate for a short period of time during and after a storm. These areas are designed to drain completely after a storm.
- **Swales:** Swales are small artificial channels that cut through

earth or rock to carry water for drainage. They retard runoff and reduce peak flow.

- **Outfall:** This is the point at which a sewer or drainage channel discharges to the sea or river. These must be capable of handling the flows released without sustaining damage during frequent events and by sustaining minimal damage during a major storm event.
- **Storm Sewers:** Storm sewers conducts storm drainage after a heavy rainfall from a building or road directly to the outfall or to a treatment facility.
- **Inlet:** This is an entrance or orifice for the admission of runoff located at the transition between open surface flow and a closed conduit system.
- **Feeder Pipes:** These pipes serve to conduct water to a larger pipe.
- **Natural Streams:** Natural streams normally adjust their cross section and slope so that they are normally at peak flow rate.
- **Street System:** Streets are an integral part of the system and their coordination with drainage and design is essential to conserve costs, to avoid problems and to enhance the neighborhood.
- **Emergency Outflow Routes:** Designers must consider the possibility of flow exceeding the capacity of the conduits and the overflow routes which will be the least destructive to the surrounding environment.

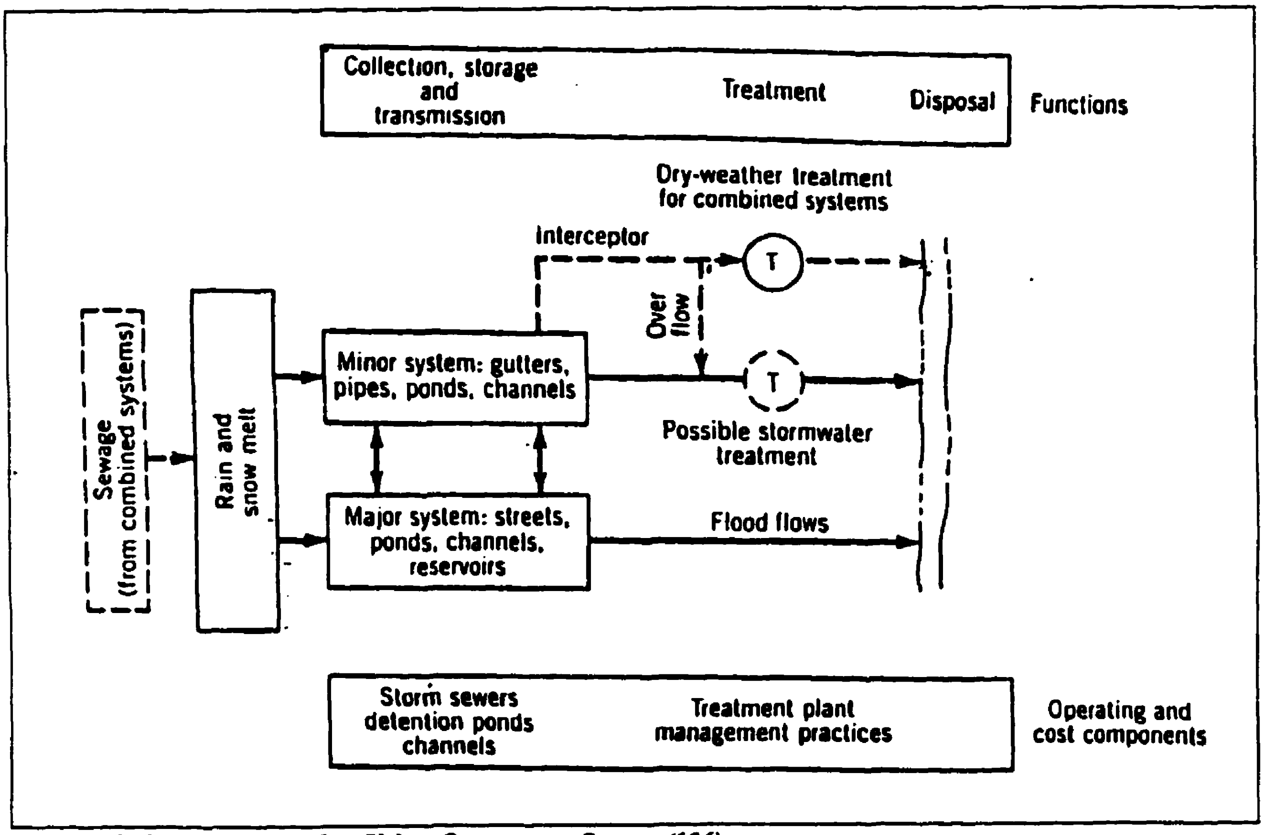


Figure 2.2 Configuration of an Urban Stormwater System (106)

2.4.3 Wastewater Disposal

The services provided by wastewater systems are to remove the wastewater form dwellings and businesses, and to provide for pollution control by proper treatment of the wastewater. Figure 2.3 illustrates the configuration of an urban wastewater management system. The wastewater systems begins with the collection system compressed of sewers. There are three distinct types of sewers (195):

- **Sanitary:** Sanitary sewers carry away the wastewater from residential and industrial buildings.
- **Storm:** Storm sewers carry the runoff from rain collected from roofs, roads, and other surfaces.
- **Combined:** Combined sewers carry both sewage and storm water.

Sewer systems consist of a network of pipes that are generally buried below the street level. The connections from individual sites terminate in submains and these in turn empty into trunk sewers, which lead to the treatment plants. After treatment the water is discharged through an outfall sewer to a nearby waterway. The quantity of sewage treated are clearly related to the amounts of water supplied to the given facility.

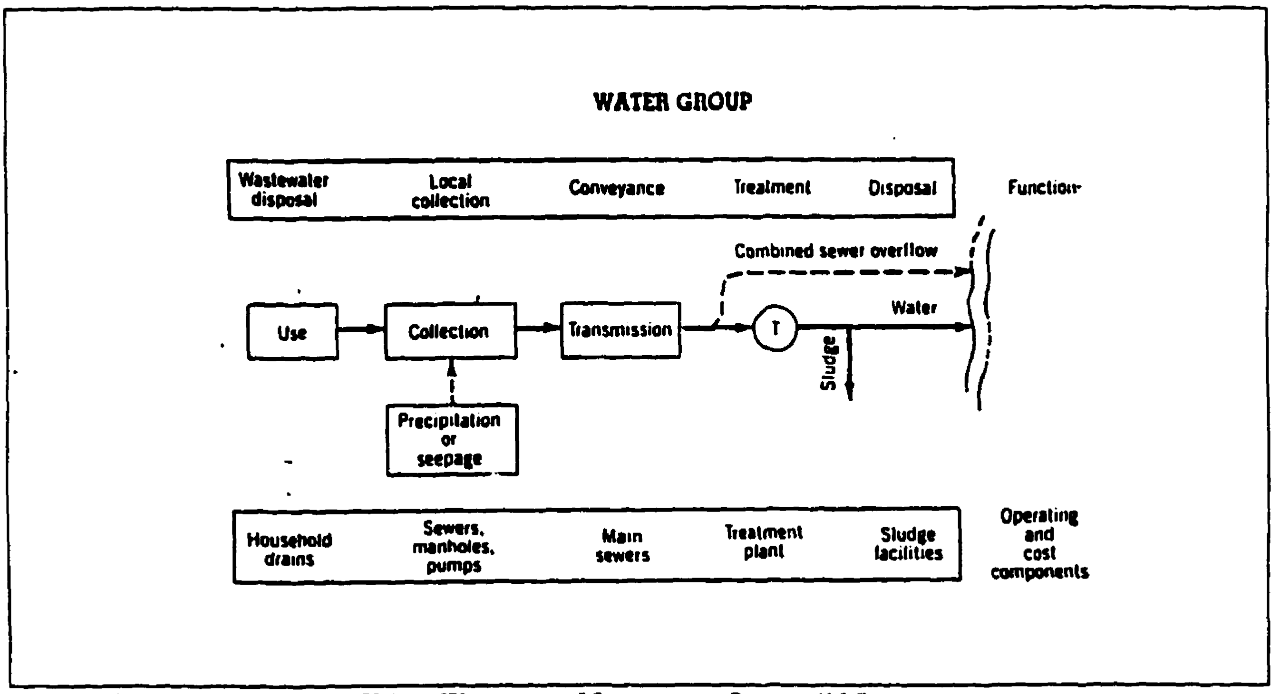


Figure 2.3 Configuration of an Urban Wastewater Management System (106)

For sparse settlements, on-site sewage treatment is usually possible. This is accomplished by installing septic tanks with drainage fields as shown in Figure 2.4. The size of these facilities depends on the capability of the soil to absorb the effluent.

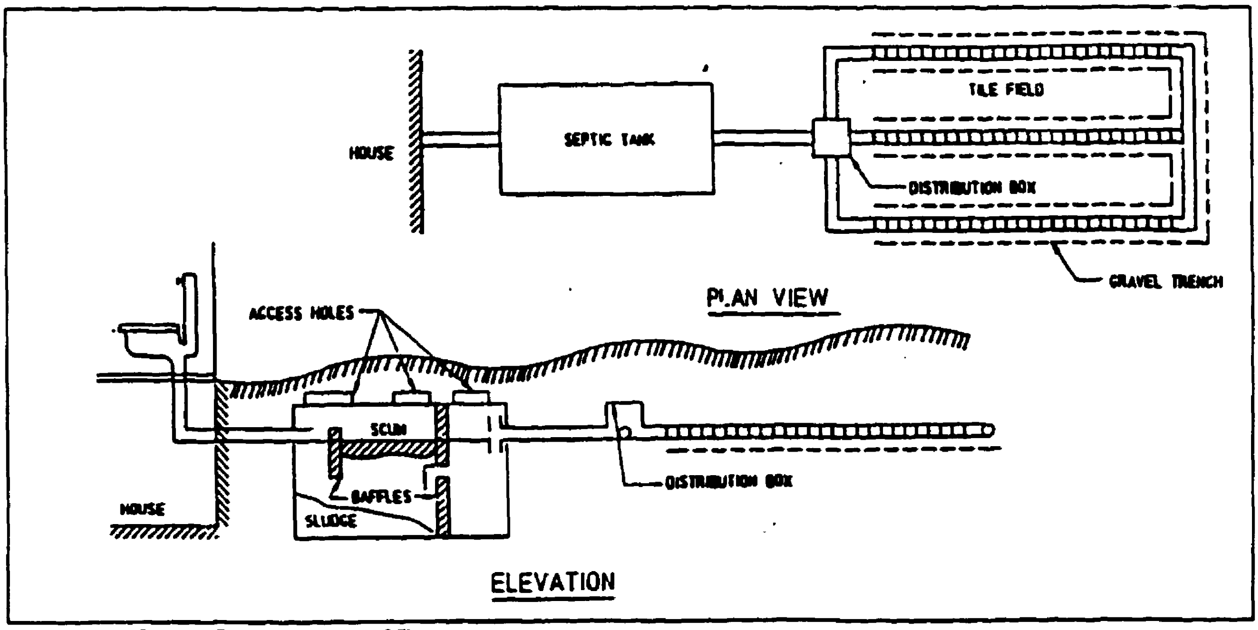


Figure 2.4 Septic Tank Layout (195)

Primary treatment is provided for all sewage entering a treatment plant and it can remove 50% to 60% of the suspended solids and 30% to 50% of the **BOD** (biological oxygen demand). This consists of coarse **bar screens** that remove large floating materials. The material is disposed of by raking the screens automatically, and a **circular grinder** reduces the material that passes through the screens into smaller particles. The velocity of approach is reduced by a **grit member** to allow for the settlement of heavier particles. A **settling tank** follows which keeps the turbulence to a minimum and the retention time is made as long as possible. The organic matter that floats to the top is called **scum** and the material that settles at the bottom is called **raw sludge**. The solids settling at the bottom are removed by scrapers through a pipe into a sludge tank. Rotating skimmers in the primary clarifer move across the surface of the water to remove grease and the clarified liquid escapes through a weir at the top of the tank.

The purpose of the secondary treatment is to reduce the BOD. This is accomplished by facilitating the microbial action of the microorganisms through a variety of methods. In a **trickling filter**, a rotating arm spreads the liquid waste over a filter bed consisting of fist-sized rocks. An active biological growth known as **slimes** forms on the rocks, and the microorganisms obtain their food from the waste over the rocks. The effluent flows through the final sedimentation tank to remove the dead organic matter from the filter stones and any final particles that may have escaped the filter.

Another type of secondary treatment is the **activated sludge system**. Effluent from the primary clarifer is brought to an aeration tank full of microorganisms and air is bubbled through this tank to provide the oxygen necessary for the survival of these aerobic organisms. As the microorganisms come into contact with the dissolved organics, they are rapidly absorbed and decomposed into CO_2, H_2O, some stable compounds and more organisms. The sewage then passes to the final settling tank and most of the sludge that settles here goes to sludge holding tanks, and the rest is returned to the aeration tank to speed the decomposition process. Secondary treatment can reduce suspended solids by 85% to 95%, BOD by 80% to 95%, and coliforms by 90% to 95%. Figure 2.5 illustrates a secondary treatment water pollution control plant.

Tertiary treatment is provided where specific pollutants exist and the receiving waterways are very sensitive. This can be in the form of microstrainer for the removal of solids, oxidation ponds for BOD removal, activated carbon adsorption for the removal of organics and inorganics, alum dosing for phosphate removal and other physiochemical processes. Tertiary treatment results in the removal of 98% to 99% of BOD.

Sludge consists of 95% of water and is treated before disposal. It is placed in a settling tank called a thickener where after settling for a period of 12 to 24 hours, a large amount of water separates from the sludge and is returned for the beginning of the process. Aerobic digestion takes place in the digester, where the remaining sediment from the primary or secondary clarification has been collected. This process reduces 50% to 60% of the volatile solids. The digestion process occurs naturally over time and the digested sludge is dried in large open beds, or by a vacuum filler. The dried sludge is either used as a landfill or dumped into the sea .

A treatment plant needs to be designed for the ultimate capacity of the area to be served. It must be located in the vicinity of a receiving water course and located at the lowest point in the area, so that the minimal amount of pumping is required. It should be located away from residential uses due to its visual impact and the existence of odors (195).

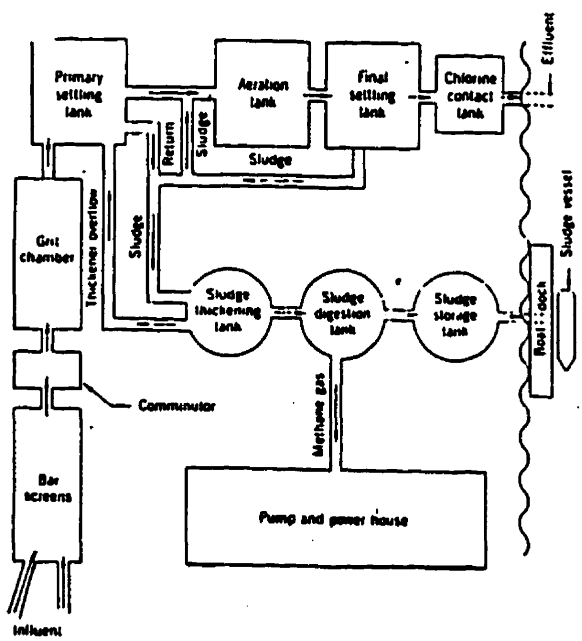


Figure 2.5 Secondary Treatment Plant (195)

2.4.4 Water Front

There are several types of waterfront structures and their uses include commerce, industry, shipping, erosion protection, and transportation. Some of the fixed structures found at the waterfront are (293):

- **Piers:** These are structures supported by a grid of bearing piles that are usually friction piles but can be driven to bedrock to support the heavy loads. They are situated at an angle to the shoreline and constructed perpendicular to a bulkhead or retaining wall.

- **Wharves:** Wharves are similar to piers in construction and function, but they are parallel to the shoreline. They are usually constructed at container ports to serve as loading platforms for materials lifted from ships using huge container cranes.
- **Platforms:** Platforms are built on piles designed to support large-scale projects. They are designed for commercial or industrial use, and are an alternative to landfilling.
- **Bulkheads:** These are vertical structures placed at the edge of a land area to retain the earth while protecting the landmass from erosion from the water on the opposite side. They can be constructed of wood sheeting, steel sheet piling, or concrete.
- **Retaining Walls:** Riprap walls are retaining walls constructed of large rocks or pieces of concrete.
- **Groins:** Groins are narrow structures built perpendicular to the coastline to protect beachfronts from erosion due to tides and waves. They can be used as fishing platforms or pedestrian areas.
- **Breakwaters:** These are placed in the water to protect harbors, mooring areas, and piers form damage caused by wave action, ice flows, and storm winds.

2.5 SUMMARY

Infrastructure systems form the foundation that support basic economic activity and a high standard of living. At times, the costs and provisions of certain kinds of infrastructure systems are shared between the public and private sectors, while for others it is borne entirely by the governments. Economic infrastructure supports productive activities such as power generation, clean water and waste removal, economic movement of goods by means of transportation systems, and communications. Social infrastructure is comprised of educational and health facilities, and public buildings. Before civil engineers attempt to repair our existing infrastructure and design new facilities, they should be aware of all components of the different infrastructure facilities and services that exist.

3.0 SUSTAINABLE DEVELOPMENT

3.1 INTRODUCTION

The concept of "Sustainable Development" was proposed by the World Commission on Environment and Development (or WCED) in 1987. WCED was formed by the United Nations in 1984. The Prime Minister of Norway, Gro Harlem Brundtland, served as its Chairman. The Commission included 23 members for 22 countries. The Commission and its staff studied the conflicts between the growing environmental problems and the desperate needs of developing nations and published its findings in the report, *Our Common Future* (200).

The human population has skyrocketed in the last 200 years, after thousands of years of slow growth. With industrialization, this rise in population has produced non-sustainable demands on our global environment. WCED concluded that it is *technically* possible to provide the minimum needs of roughly twice the present population during the next century -- on a sustained basis and without continued degradation of the world's ecosystems (200).

Unsustainable activities today are illustrated by the following facts (200):

- The human population has increased by six times since the beginning of the industrial revolution (about 1790). The population has tripled since 1900. It will double again within 40-50 years.
- In this century, global economic output has increased by a factor of 20.
- The use of fossil fuels has increased by 30 times in the same period.
- Industrial production has increased by a factor of 100 times in the past 100 years.
- As the result of all this, 25% of the world's population in industrialized nations consumes about 80% of the world's goods.
- Increased consumption has led to increased waste products, which in turn produced environmental degradation.
- For example, forests are being destroyed at the rate of 100,000 square kilometers per year. This is an area larger than The Netherlands and Switzerland combined, or an area even larger than Tasmania.
- Finally, during this century the annual loss of plant and animal species through extinction has changed from about four per *year* to more than four species per *hour*.

3.2 DEFINITION OF SUSTAINABLE DEVELOPMENT

There is no single definition for sustainable development. It is basically an effort to use technology to help clean up the "mess" created by the thoughtless and reckless use of the available natural and man-made resources and modern technology without consideration of its total consequences to the society. According to one of its popular definition, sustainable development " is a matter of satisfying the needs of present generations without compromising the ability of future generations to satisfy their own needs." (36)

The Brundtlund Commission defined it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (138 p.17). The Civil Engineering Research Foundation (CERF) defined it as "...the challenge of meeting growing human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development." (36)

Here are some other common descriptions of sustainable development (237):

> *"Then I say the earth belongs to each . . . generation during its course, fully and in its own right, no generation can contract debts greater than may be paid during the course of its own existence."* -- ***Thomas Jefferson, September 6, 1789.***
>
> *"Sustainability refers to the ability of a society, ecosystem, or any such ongoing system to continue functioning into the indefinite future without being forced into decline through exhaustion. . . of key resources."* -- ***Robert Gilman, President of Context Institute.***
>
> *"Sustainability is the [emerging] doctrine that economic growth and development must take place, and be maintained over time, within the limits set by ecology in the broadest sense - by the interrelations of human beings and their works, the biosphere and the physical and chemical laws that govern it . . . It follows that environmental protection and economic development are complementary rather than antagonistic processes."* -- ***William D.***

Ruckelshaus, "Toward a Sustainable World," Scientific American, September 1989.

"The word sustainable has roots in the Latin subtenir, meaning 'to hold up' or 'to support from below.' A community must be supported from below - by its inhabitants, present and future. Certain places, through the peculiar combination of physical, cultural, and, perhaps, spiritual characteristics, inspire people to care for their community. Theses are the places where sustainability has the best chance of taking hold." — ***Muscoe Martin, "A Sustainable Community Profile," from Places, Winter 1995.***

3.3 THE CURRENT STATE OF OUR PLANET

The growth of world economy is matched by the environmental problems created by it. Even remote regions in the world are affected by this phenomenon. The present generation is following a non-sustainable and environmentally destructive way of life, which threatens the very existence and quality of life as it should be on this planet for not just the present generation, but more importantly for the future generations. Therefore the rights of the future generations to lead a normal and healthy life must not be denied or left unconsidered, because at the present rate, this seems quite unattainable for most of the present generation. A few of the environmental problems being currently faced are (138):

- Deterioration of the quality of our air, water, soil and natural habitat for all species;
- Garbage crisis;
- Rapidly increasing population;
- Huge appetite for energy;
- Depletion of natural resources;
- Deforestation;
- Deterioration of the ozone layer;
- Global warming,
- Accumulation of toxins;
- Extinction of species;
- Oil spills;
- Shortage of fertile land, fresh water and fossil energy, etc.

The present generation is quite aware of the crisis being faced by our planet, but it is not undertaking urgent action to find appropriate remedies. In summary, some realization of the graveness of the problem exists presently, however the urgently required actions either do not exist, or they have not been given due consideration..

If the general population in all parts of the world had been uniformly responsible for all of the above problems, it may be understandable (but not acceptable), since the world population is growing at an alarming rate. But what makes the current situation more horrifying is that it is the result of only 20% of the planet's population consuming about 80% of the world resources, and these very people control 82.7% of the world's wealth. Most of the remaining 80% live in poverty (138). In other words, there is an extremely unfair distribution of wealth. To top this, the less wealthy nations have very little hope of getting themselves out of poverty and set themselves towards development because they are extremely indebted to the developed nations. Much of their income and most productive land is used to pay off their debts or the interests on their loan to the wealthy nations, banks and other investors.

Multinational corporations also pose major problems for developing nations. Many of them are far more wealthier than most developing nations. Their goal is not prosperity for the country where they are located or whom they serve, but to make a profit. They "profit by reorienting local economies away from small scale solutions and local self-sufficiency." (3) This results in the loss of local control to outsiders which can then lead to the developing nation being controlled by the multinational corporations and the developed nations where they are based.

This way of life cannot continue indefinitely for the developing nations because it will not be long before these nations demand their share of the global resources and the standard of living enjoyed by the wealthy nations. This phenomenon has started to emerge. China and India, which constitute a major portion of the world population, are both experiencing an increase in economic development and consumerism at an alarming rate. Although this development is good for these nations, it will lead to the collapse of our global environment, and the only way this can be slowed down is by sharing the current resources available. But the idea of having to cut down consumption by those residing in the wealthy nations and sharing it with the developing nations, would be quite unacceptable and impossible to achieve.

Therefore, it is quite clear that the planet is facing a grave crisis in terms of its natural resources and environment. The standard of living enjoyed by the wealthy nations cannot be sustained for much longer if the consumption of global resources continues at the current rate and no immediate action is taken. Sustainability of our resources needs to be urgently addressed. Drastic changes in our way of life need to be made at some point in our lives. There is a strong need not only to come to terms with the current environmental and sustainability problems, but it must also be recognized that some serious actions needs to be taken urgently on their part as well.

3.4 UNCED CONFERENCE IN RIO DE JANEIRO

In 1987, the World Commission on Environment and Development (WCED) proposed the following objectives for sustainable development (115):

- Reviving growth;
- Changing the quality of growth;
- Meeting the essential needs for jobs, food, energy, water and sanitation;
- Conserving and enhancing the resource base;
- Reorienting technology and managing risk; and
- Merging economics and environment in the decision making process.

The UNCED Conference in Rio De Janeiro, June 1992, brought the global community together and established future commitments for a sustainable future. The outputs were (218):

1. The Rio Declaration on Environment and Development;
2. 'Agenda 21 ', the pathway to sustainable development in the 21st Century;
3. A statement on Forest Management Principles;
4. The UN Framework Convention on Biological Diversity, opened for signature, and signed by 153 countries at the conference; and
5. The UN Framework Convention on Climate Change, opened for signature, and signed by 153 countries at the conference.

The Rio Declaration represents a set of 27 agreed principles aimed at the objective of 'a new and equitable global partnership', 'international agreements that respect the interests of all and protect the integrity of the global environment and developmental system', and recognition of 'the integral and interdependent nature of Earth, our home'. Some of the principles are summarized below (218):

- Humans are entitled to a healthy and productive life in harmony with nature.
- The environmental and developmental needs of future generations should be heeded.
- All states and people shall cooperate-operate to reduce poverty.
- The situation and needs of developing countries shall be given special priority.

- States shall cooperate-operate in global partnership to conserve, protect and restore the health and integrity of the Earth's ecosystem.
- States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies.
- States shall cooperate-operate to strengthen endogenous capacity building.
- Environmental issues are best handled with the participation of all concerned citizens.
- States should enact effective environmental legislation.
- The precautionary approach shall be widely applied.
- National authorities should promote the internalization of environmental costs. The polluter should bear the cost of pollution.
- Environmental impact assessment shall be used for activities likely to have an adverse effect on the environment.
- States shall immediately notify other states of natural disasters likely to produce sudden harmful effects.
- Indigenous people have a vital role in environmental management and development.
- Warfare is inherently destructive of sustainable development. Peace, development and environmental protection are interdependent and indivisible.

Agenda 21 is the operational plan for moving humankind into the age of sustainability and should be read and given profound consideration by all people, including all engineers. More than half the sections of 'Agenda 21 ' are of direct or indirect relevance to science and technology (e.g. those dealing with the protection of human health, human settlement, integration of environment and development in decision making, protection of the atmosphere, integrated approaches to the planning and management of land resources, combating desertification and drought, sustainable mountain development, conservation of biological diversity, environmentally sound management of biotechnology, toxic chemicals, hazardous wastes, solid wastes, radioactive wastes, scientific and technological community, transfer of environmentally sound technology, education, national mechanisms, institutional arrangements, and information.)

3.5 SUSTAINABLE DEVELOPMENT, ENGINEERING AND TECHNOLOGY

The Council of Academies of Engineering and Technological Sciences (CAETS) was founded in 1978 and consists of 14 national academies. These academies represent the engineering and technological leadership in their respective countries. The Council agreed to the enclosed declaration on the important role of technology in a sustainable future for humanity at its biennial Convocation in Kiruna, Sweden, in June 1995. It focuses on the critical role of technology in assisting the society to achieve environmentally sustainable economic growth. The theme of the conference was "Creating Wealth in Harmony with the Environment - the Role of Engineers and their Academies".

One purpose of this declaration is to communicate the importance of engineering and technology to national and international organizations including governments. In addition, it is also intended to make them aware of the intellectual resources of the world's engineering community, as represented by CAETS and its members, resources that could be made available both to help solve problems and to indicate the direction that should be taken to address society's needs.

The Council believes that sustainability can be achieved only if great attention is given to two key areas: environmental quality and economic development. Since the primary opportunities to pursue these twin goals are technological in nature, in both developed and developing economies, technology and engineering issues are pivotal. The choices of producers and consumers about product technology, process technologies, levels of investments in research and development, the rates of diffusion of technologies, and the design of government regulations affecting innovation are critical as societies move toward sustainable development.

The Council subscribes to the following (237):

- Engineering and technology are key components of national and international efforts to achieve environmentally sustainable economic development for all nations;
- The goals of economic development and environmental protection can and should be compatible;
- The ability to achieve global sustainability is strongly influenced by population growth;
- Many natural systems are inherently variable. Such variability is easily confused with the impact of human activity on the environment. Distinguishing between inherent

and man-made variability in natural systems and their capacity to respond to change is an important subject for research;

- For some environmental issues (for example, those involving the oceans and atmosphere), the planet must be regarded as a single complex system whose interests are best served by coordinated international action. Both developed and developing nations have a common interest in resolving global environmental issues;
- Most actions to achieve environmentally sustainable economic development will take place at the national or local level, while at the same time taking into account the interdependence of nations. Individual countries will need to develop approaches to solving sustainability problems that are tailored to their own rate of economic development, cultures, religions, and political systems; and
- The achievement of environmentally sustainable economic development is dependent on adequate technical education at all levels and on education to balance economic, social, and environmental goals.

The Council believes that the development and use of technologies that do not harm the environment is critical to maintaining and improving the quality of life, however, the wise use of technology is a necessary but not sufficient prerequisite for sustainable development. In addition, socially compatible and environmentally sound economic development is possible only by charting a course that makes full use of environmentally advantageous technologies that utilize resources as efficiently as possible and minimize environmental harm while increasing the industrial productivity and improving the quality of life (237).

3.6 PATHWAYS TO SUSTAINABILITY

Achieving sustainable economic development will require changes in the industrial processes, in the type and amount of resources used, and in the products which are manufactured. CAETS believes that while technologies affecting all societal activities must reflect the goals of sustainable economic development, the following pathways to sustainability are among the most important (237):

Energy:

Sustainability depends on the evolution of energy technologies and the world will need to reduce the use of fossil fuels. Technical efforts need to be directed to increasing the efficiency of energy supply and energy use, and to using fossil fuels in a less-polluting manner.

In the long term, there are a variety of possibilities for securing the world's energy future through renewable energy sources. For instance, there have been rapid advances in efficient solar cell-based power, wind, and other sources of renewable energy are also becoming realistic options for niche uses. Finally, public acceptance of nuclear power will depend on the safe operation of nuclear plants and the safe management of the radioactive wastes produced by these facilities.

Public Infrastructures:

Public infrastructures are essential to the efficient functioning of society and its ability to achieve sustainable development. These include water resource and supply systems, power systems bridges, roads, as well as communications and transportation facilities. The Council feels that to a large extent the technologies are well developed and the essential challenge lies in the diffusion and use of such technologies to developing nations, where they are most needed.

Water:

Water treatment and re-use will have a decisive role in sustainable development in the public, industrial and agricultural sectors. In the public sector, securing public health will remain the basic feature of urban water systems; water transportation and treatment technologies must be chosen accordingly. Technologies now exist for controlling many types of pollutants. The future challenge will be the control of organic micro-pollutants and heavy metals.

For the water- intensive industries, minimizing water consumption will become a necessity, and for the agricultural sector, new technologies for irrigation will be needed that minimize water consumption and prevent unsustainable groundwater extraction.

Manufacturing and Mining:

Manufacturers have begun to reduce, re-use, and recycle materials and products in a search for industrial ecosystems that can imitate natural ones. In other words, wastes from one part of the system are used as inputs to the other parts of the system.

Materials:

Traditional materials, such as steel, concrete, and plastic, are undergoing significant changes that reduce the environmental impact of their manufacture and use. Scientists and engineers are also beginning to design new materials based on a better understanding of their properties and the possibility to manipulate them at the atomic level.

In the future, new technological capabilities will contribute to the creation of materials with very specific and closely controlled properties permitting the development of products that are more energy efficient, that consume less mineral resources for their manufacture, and are lighter, stronger, and recyclable. Also being developed presently are alloys lighter than aluminum and stronger than steel, and composites based on biological materials that are superior to the other materials (237).

Information Technology:

Information technology has the potential to alter how and where people work and live, and thus the nature of urban areas of the future. It is changing the way that enterprises are managed and improving the efficiency of air, land, and water-based transportation systems, along with the other sectors of the economy.

Networks of fiber optic cables and systems of Earth-orbiting satellites are extending our ability to survey and protect the environment permitting real-time monitoring of environmental conditions. From automobiles to nuclear power plants, information technologies allow precise control of industrial processes, which improves our ability to minimize pollution and improve energy efficiency.

The selection of pathways will depend on the actions of governments, international agencies, consumers, private industry, and educational institutions. While there are many obstacles to the transition to sustainable development, technology provides a means to overcome them (237).

3.7 SUSTAINABLE DEVLOPMENT AND CIVIL ENGINEERING

Sustainable development in engineering terms is a new way of thinking, planning, designing, maintaining and operating infrastructure facilities. The key aspects of sustainable development are (194):

- Efficient energy use through conservation measures;
- Switching to renewable sources;
- Waste minimization;
- Recycling;
- Reuse of materials;
- More comprehensive economic/environmental assessments using "life-cycle" analyses; and
- Better management of resources.

Engineers will be increasingly taking into account the three 3Rs: Reduce, Reuse, and Recycle. Reduce in terms of engineering means building only if it is needed and the required function cannot be fulfilled through other means. Reuse means that the new product should be reusable or that instead of building new things, attempt should be made to reuse what already exists. Recycle is basically similar to reuse but different in the sense that it can imply creating something totally different from what existed previously.

The most significant change in sustainable development approach addresses advanced planning before the projects are identified. This also means that on many projects, consulting engineers will serve as advisors rather than as decision makers. In these cases, the firms will make clear to clients the full range of environmental consequences of the various alternatives, with increased emphasis on the sustainability of natural resources and wildlife affected by the project. They will also assume the role of facilitating by listening, asking questions, clarifying solutions, and helping find alternate solutions. This will lead to a considerable increase in management of infrastructure and technology.

In the past, engineers have unintentionally contributed to global environmental problems by carrying out their basic engineering roles. The population explosion resulted from reduced death rates due to better water supplies and sanitation, assisted by the benefits of engineer-designed hospitals and health care facilities. The growing population was fed by improved agriculture which in turn was the result of engineered land reclamation, water resource development and improved agricultural engineering. Engineers made major contributions to energy development, transportation systems and industrial production. These contributions, in turn, had a profound influence on changes in consumption patterns, the generation of industrial wastes, and the resulting environmental impacts (200).

3.8 SUMMARY

It is now predicted that the world's population will stabilize at about 10 billion people within the next 40 to 50 years. The world will need five to ten times the present economic development to meet the minimum needs of this larger population. This level of expanded development may be possible through new technologies in industry and agriculture, more effective resource management, a broader sharing of resources, and better long-term management of our environment (200).

It should be noted that the principles of sustainability apply to several disciplines such as agriculture, mining, forestry, fishing, etc., in addition to engineering. To have sustainable development, major changes need to be made in our current way of life and civil engineers need to modify their current practices and adopt the principles of sustainable development. Time is running out and we need to view the 3Rs as our moral and professional responsibility, which is not going to be an easy task, however, it should be remembered that we have a great deal to lose if we continue to deplete our global resources at the current alarming rate.

We must recognize that the assault on the environment cannot be effectively controlled, but must be prevented. Prevention will require the transformation of the present structure of the techosphere (man made technological environment), bringing it into harmony with the ecosphere (natural physical environment), which would need massive redesigning of the current design, materials selection, construction methods, and development patterns. However, this change must be implemented in ways that eliminate, or very greatly reduce, the generation of pollutants by the system without hindering its ability to produce the necessary goods and services. In other words, the new techosphere must be both productive and compatible with the ecosphere (50).

4.0 THE INFRASTRUCTURE CRISIS

4.1 INTRODUCTION

The health and well-being of Canadians, along with Canada's economy, depend on basic services like roads, bridges, sewers, water supply, schools, airports, telecommunications and transit systems, which collectively form our infrastructure (80). There was an urgent need for new infrastructure after the Second World War due to a significant growth in Canada's population. This development of new infrastructure continued well into the 1960s due to (31):

- The "baby boom";
- Significant immigration levels: and
- Increase in urbanization.

The 1970s decade was marked by a period of population growth of about 27% (79), and as growth started to slow in the late 1970s, so did the pace of infrastructure expansion. However, in the 1980s the trend of moving into new and larger homes in less dense areas and urban sprawl placed a major burden on the existing infrastructure facilities and began absorbing any excess capacity left in them, resulting in a demand for new infrastructure. Until the 1970s, this infrastructure was maintained at an acceptable level due to the favorable economic conditions and also because most of these facilities were fairly new. However, the situation started to change and the backlog of maintenance and replacement work began to grow (80). In addition, the phenomenon of urban sprawl further compounded the infrastructure problem (79).

Currently in Canada, infrastructure consumes over $11 billion per year (31), mostly towards new construction and not enough for maintenance and repair. Expenditures on repair constitute only 20% of the spending on the infrastructure which has led to the current deplorable state of our urban infrastructure.

A sound infrastructure is essential to the long term economic growth and public health. Economic productivity and efficiency along with public health are linked closely to adequate transportation, water quality and waste disposal. Recently, several factors have contributed in creating problems for municipal infrastructure (80):

- Pressure on budgets during recession;
- Some post-second world war infrastructure approaching the end of its life span;

- Rapid inflation of the 1970s;
- Competing demands for municipal services ;
- Reluctance to borrow at high interest rates prevalent in the 1980s;
- Increased public involvement in decision-making; and
- Reduction in private, federal, provincial and municipal funds.

This chapter describes the state of urban infrastructure in Canada and the US and the causes that led to the current infrastructure crisis.

4.2 STATE OF URBAN INFRASTRUCTURE IN NORTH AMERICA

4.2.1 Studies in North America

In 1983, the Federation of Canadian Municipalities (FCM) created a Task Force and a Technical Committee on Municipal Infrastructure. A questionnaire was then sent out to all FCM members and to selected non-members to examine the state of infrastructure. In January, 1985, the FCM published the results in a report entitled, "Municipal Infrastructure in Canada: Physical Condition and Funding Adequacy".

The American study most similar to the Canadian survey undertaken by the FCM in 1984 is a joint study conducted by the National League of Cities and the US Conference of Mayors in 1983, based on 809 responses out of a total of 1,400 municipalities surveyed. In addition, the American Public Works Association (APWA) surveyed a few large cities in the US and Canada. In addition, a joint infrastructure survey of 809 municipalities was undertaken by the National League of Cities and the United States Conference of Mayors (USCM-NLC). Both these surveys were concerned with municipal infrastructure needs and expenditures (133).

Due to the rapidly increasing deterioration of Canada's infrastructure and the escalating costs of its rehabilitation necessitated that the status of Canadian municipal infrastructure be updated. Therefore, a survey was undertaken in 1995 by McGill University, in conjunction with the Federation of Canadian Municipalities, to update the information available on the current status of Canadian municipal infrastructure. The survey responses were used to compare the present state of the municipal infrastructure with its condition in 1985 to help establish the present-day priorities in infrastructure renewal. The goal of the report was to inform the different orders of government of the current situation of the infrastructure crisis and recommend appropriate actions that may be necessary in the broad interests of the Canadian society.

The survey questionnaire, which was sent to 589 FCM members, was designed to develop both qualitative and quantitative assessment of the condition of the Canadian infrastructure. Furthermore, the survey was designed to measure the success of the Canadian Infrastructure Works Program. The objectives of the McGill/FCM survey on the state of Canadian municipal infrastructure were the following (209):

- Update the information available on the state of Canadian municipal infrastructure;
- Compare the present state of municipal infrastructure with that in 1985;
- Re-establish the priorities in infrastructure renewal; and
- Study the success of the current Infrastructure Works Program.

In general, the results of the survey provided answers to the following questions:

- To what extent has Canada's municipal infrastructure deteriorated over the past 10 years ?
- What are the impediments to successful rehabilitation and maintenance of the infrastructure?
- What is the average age of the existing infrastructure?
- What are the sources of revenue for operation, replacement and rehabilitation?
- What is the total cost to bring the existing infrastructure to an acceptable level?
- How effective is the current Infrastructure Works Program ?
- Has this program funded the right projects?
- What are the short-term and long-term needs of the municipalities and other organizations?

The analysis was conducted for four different population groups in order to compare the differences in the results and to find out if the needs of each population group differed from one another. The municipalities were divided into the following population groups:

- **Group 1:** Population below 10,000
- **Group 2:** Population between 10,000 and 100,000
- **Group 3:** Population between 100,000 and 400,000
- **Group 4:** Population above 400,000

4.2.2 Condition of North American Infrastructure in the 1980s

Today, local governments are facing an infrastructure crisis of frightening proportions due to years of neglect requiring costly repair, rehabilitation and replacement. There has been a steady decline in the state of our infrastructure over the past two decades and these facilities are now inadequate to meet the current requirements and to support the projected future growth and development. Infrastructure continues to be in serious need of repair and upgrading. In addition, repair costs are escalating. Once deterioration sets in, it compounds exponentially, becoming more difficult and expensive to repair. It was estimated in the eighties that it will cost US $ 1 trillion by the year 2000, and US $ 3 trillion in the next 20 years just to replace and repair our current infrastructure (189). According to the US department of Transportation, "By the mid-1990s, deteriorating infrastructure will have cost our nation almost 6% in disposable income, 2% in employment growth, and nearly 3% in manufacturing productivity" (192).

A considerable percentage of the infrastructure has exceeded its useful life. It is not unusual to find sewers that are between fifty and seventy-five years old. Deterioration of infrastructure facilities is escalating due to deferred maintenance, which has resulted in the collapse and closing down of certain facilities such as bridges and water and sewage lines. Service disruptions are becoming a common occurrence.

The 1985 FCM study concluded that essential services such as roads, bridges, sidewalks and sewer systems were in poorer condition than community and social service facilities like parks and libraries, or community centers. In many communities, it was found that the condition of the essential facilities was deteriorating, while the social services were regarded as improving. Water treatment and sewage treatment facilities seemed to be in good shape because they were relatively young. The costs to upgrade the infrastructure facilities was estimated at $12 billion in 1985 (79 & 80); this cost rose to $20 billion in 1992 (80).

In 1992, the FCM distributed a "green card" questionnaire to delegates at the Annual Conference in Montreal. Results indicated that infrastructure renewal priorities had shifted from roads, bridges and sidewalks to sewers (81), reflecting the change in infrastructure priorities over time.

An American study similar to the one conducted by the FCM , "Capital Budgeting and Infrastructure in American Cities: An Initial Assessment", was conducted by the National League of Cities and the United States Conference of Mayors (NLC/USCM) in early 1985. By comparing the results of the two studies, it was found that Canadian Infrastructure is in a better condition than its US counterpart. In addition, the same facilities were judged to be in the poorest condition in both countries: roads, bridges, sidewalks, storm and sanitary sewers (80).

A National Council on Public Works Improvement (US) report in 1988, studied categories of infrastructure representing a capital stock of US $1 trillion, representing 10 percent of the nation's total capital stock. Public spending on these facilities exceeds US $100 billion annually, accounting for 7 percent of all government spending, which emphasized that public works are a major source of employment in construction, operation and maintenance, and to keep America competitive, capital spending on infrastructure needs to be increased by 100 percent (163).

The council found that the quality of America's infrastructure is barely adequate to fulfill current requirements, and insufficient to meet the demands of future economic growth and development. Most major categories of infrastructure in the US are performing only at passable levels. A few, such as water supply and water resources, remain in reasonably good shape, while others such as solid waste and hazardous waste disposal, have serious growth problems. The report card in Figure 4.1 provides an overview of the performance of eight categories of infrastructure of public works (164).

According to the American Association of School Administrators, 31% of the American public schools were built before World War II and the national cost of deferred school repairs is now estimated at over $100 billion (105).

There is a close correlation between the Canadian and US studies for most facilities. In both countries, roads and pavements were judged to be in great need of repair. Water treatment and distribution systems appeared to be in basically good condition. Sewage treatment facilities, storm sewers and bridges appeared to be of greater concern in the US than in Canada. Sewage collection systems seemed to be of about equal concern to both countries. Overall, it could be said that the condition of the infrastructure in Canadian cities is better than in cities in the US. However, this is probably due to the fact that the Canadian infrastructure is newer (120).

Canadian municipalities receive less federal government funding than the American municipalities and considerably less than the European cities. In addition, the US recognized the infrastructure crisis earlier than Canada in the early 1980s and began to deal with it immediately (80).

Except for a survey of municipal infrastructure by the Institution of Civil Engineers in Britain, there have been no comprehensive national infrastructure condition and needs assessments in Europe. North American participants in a European infrastructure study tour found that in general European cities have tended to maintain their infrastructure better that the North Americans. In addition, European officials indicated that there was far less backlog of work needed to upgrade their systems than has been reported in North America (133).

In general, infrastructure conditions in Europe appear to be better than in Canada largely due to better management of maintenance and replacement programs. In most European countries, there is central or federal government funding for local maintenance, and since some European governments are involved in profitable enterprises, such as banking and mining, there are additional revenues to offset the cost of some local government services. However, there have been no national infrastructure surveys in

Europe and information retrieval systems for infrastructure are not as advanced as in North America. But Europeans are in the process of setting service standards for infrastructure management systems (80). In Canada, the National Research Council (NRC) has proposed a development of infrastructure guidelines.

The World Economic Forum/Institute for Management Development (WEF/IMD) ranked the positions of the different countries with respect to its infrastructure using the broad definition of infrastructure as "the extent to which resources and systems are adequate to serve the basic needs of business" (175). It ranked Canada 5th out of 22 developed countries. Norway, Switzerland, Sweden and Denmark ranked in the top four. Canada's rankings for specific aspects of infrastructure are shown in Table 4.1. The infrastructure investments required in Asia and some selected countries are summarized in Table 4.2.

Table 4.1: WEF/IMD Ranking of Canada's Infrastructure (175)

Rank (of 22)	Aspect of National Infrastructure Related to Competitiveness
8	Road Transport
5	Air Transport
7	Railroads
11	Water Treatment
15	Municipal Waste per Capita

Table 4.2: Infrastructure Investment Needed (175 & 209)

$US	Country or Region
2.5 trillion	Asia (not including Japan)
1.9 trillion	East Germany
4.0 trillion	former Soviet Bloc
1.0 trillion	US
5.3 trillion	Japan
31.4 billion	Canada

Subject Category	Grade	Successes/ Recent Changes	Problems/ Future Weaknesses
HIGHWAYS	C+	Federal and state gas tax increases have injected new capital into the system. This, along with increased O&M spending, has improved pavement conditions. However, quality of service in terms of congestion is declining.	Spending for system expansion has fallen short of need in high-growth urban and suburban areas. Many roadways and bridges are aging and require major work. Needs of most rural and smaller systems exceed available resources. Highway Trust Fund has a sizeable cash balance.
MASS TRANSIT	C-	Federal capital grants have helped improve quality of service in some areas, but overall productivity of the system has declined significantly. Growth of transit vehicles is double the rate of increase in ridership. Diverting people from cars is increasingly difficult.	Mass transit is overcapitalized in many smaller cities and inadequate in large, older cities. Systems rarely are linked to land-use planning and broader transportation goals. Maintenance has been erratic and inadequate, especially in older cities.
AVIATION	B-	In general, the aviation system has handled rapid increases in demand safely and effectively. However, service has begun to decline in the face of increasing airport and airspace congestion as a result of strong traffic growth. The air traffic control system is currently undergoing a $16 billion modernization.	Congestion is the system's primary problem. Despite recent increases in authorizations, sizeable cash balance remains unspent in the Airport and Airway Trust Fund. The air traffic control system needs substantial upgrading to maintain safety.
WATER RESOURCES	B	Water Resources Act of 1986 made cost-sharing mandatory for many types of water projects. This change should improve project selection and reduce overall project costs.	Cost-sharing will improve efficiency but also increase local costs of water projects. Poorer communities may find it difficult to finance projects. Implementation is often excessively slow and cumbersome.
WATER SUPPLY	B-	While regional performance varies, water supply stands out as an effective, locally-operated program. Strict new standards created by the 1986 Safe Drinking Water Act will require drastic increases in water rates over the next decade.	Many public water systems suffer from pricing below costs, inability to meet purity standards, or source contamination. Storage and distribution systems are deteriorating in some older cities and supplies are limited in some parts of the West and several cities along the East coast.
WASTEWATER	C	Over 75% of U.S. population is served by secondary treatment plants. Shift from federal grants to state revolving loans may improve efficiency of plant construction. Broadened focus on nonpoint source pollution and groundwater contamination may accelerate progress toward cleaner water.	Despite $44 billion federal investment in sewage treatment since 1972, water quality has not improved significantly. This is due in part to uncontrolled sources of pollution, such as run-off from farmland and roadways. Overall productivity of secondary treatment facilities is declining, resulting in an increase in water quality violations.
SOLID WASTE	C-	Testing and monitoring of solid waste facilities are more rigorous as a result of tougher environmental standards. Waste-to-energy technology is growing as alternative to landfills. More aggressive waste reduction, separation, and recycling efforts are beginning at the local level. However, few states have moved boldly on these measures.	Nation faces significant costs of adequate and safe facilities. Limited data suggest trends toward fewer but safer landfills, rapid growth in resource recovery, and little progress toward waste reduction. Public opposition to siting all types of facilities is a major problem.
HAZARDOUS WASTE	D	Funding for site clean-up has increased five-fold since 1986, but progress has been slower than expected. Only a small fraction of the two tons of waste per capita produced in America each year is being treated safely. Major challenge is still ahead of us.	Nation has forfeited much of its opportunity to reduce waste before it is produced. Waste control legislation promotes "end-of-pipe" rather than source reduction solutions. Congressional mandates and schedules may be overly optimistic, given administrative resources. A massive backlog of poisons and needed cleanup projects faces the nation.

Figure 4.1 Report Card on the Condition of Infrastructure in the US (164)

4.2.3 Condition of Canadian Infrastructure in the 1990s

The average age of all of the infrastructure facilities was determined for each population group of the 1995 McGill/FCM Survey, to compare the aging trend in each of the population categories. The average age for all of the responding municipalities is tabulated in Table 4.3.

Table 4.3: Average Age of Infrastructure Facilities for all the Responding Municipalities (209)

Facility	Average Age
Sanitary and combined sewers	42
Water distribution	37
Water supply	36
Storm	32
Bridges	32
Roads	29
Sidewalks	27
Community and social services	26
Curbs	25
Sewage	24
Parks and recreational facilities	22
Solid waste	15
Transit	13
Public buildings	10
Hazardous waste	4

At the national level, sanitary and combined sewerage, water distribution and water supply are the oldest infrastructure systems, at average ages of 42, 37, and 36 years, respectively, while transit, public buildings in the municipal sector and hazardous waste are the youngest facilities, at 13,10, and 4 years, respectively. The infrastructure facilities for the fourth population group were the oldest as expected, and the trend differed only slightly between each population group.

Table 4.4 lists the infrastructure facilities in descending order of change in the condition of the infrastructure as assessed by the respondents. It can be seen that at the national level, only parks and recreational facilities are improving; transit, roads and curbs are getting worse, and the rest have remained almost the same over the last 10 years. For the first population group, roads, sidewalks and curbs are getting worse. For the second population group, sanitary and combined sewers and roads are getting worse and for the third population group, hazardous waste, water distribution and solid waste are improving. The change in the condition of the infrastructure facilities in the fourth population groups are similar to that at the national level since the results were weighted according to the population and this population group would have the most effect on the results. Roads were found to be getting worse in all population groups. It can be pointed out that most infrastructure facilities are about the same in condition as they were 10 years ago.

Table 4.4: Comparison of Change in Condition of Infrastructure for all Population Groups (209)

Change in Condition	General	Group 1	Group 2	Group 3	Group 4
Improving	1. Parks & Rec. Facilities	1. Hazardous Waste 2. Parks & Rec. Facilities 3. Water Supply 4. Water Distribution 5. Sanitary & Combined Sewerage	1. Hazardous Waste 2. Water Supply 3. Solid Waste 4. Water Distribution 5. Parks & Rec. Facilities 6. Public Buildings 7. Bridges 8. Sewage Treatment	1. Hazardous Waste 2. Water Distribution 3. Solid Waste	1. Parks & Rec. Facilities
About the same	1. Hazardous Waste 2. Solid Waste 3. Storm Sewers 4. Community & Social Services 5. Sewage Treatment 6. Public Buildings 7. Water Supply 8. Sanitary & Combined Sewers 9. Water Distribution 10. Bridges 11. Sidewalks	1. Transit 2. Public Buildings 3. Community & Social Services 4. Bridges 5. Storm Sewers 6. Sewage Treatment 7. Solid Waste	1. Storm Sewers 2. Transit 3. Community & Social Services 4. Curbs 5. Sidewalks	1. Curbs 2. Community & Social Services 3. Sewage Treatment 4. Water Supply 5. Bridges 6. Public Buildings	1. Hazardous Waste 2. Solid Waste 3. Storm Sewers 4. Public Buildings 5. Sewage Treatment 6. Community & Social Services 7. Water Supply 8. Sanitary & Combined Sewers 9. Sidewalks 10. Water Distribution
Getting Worse	1. Transit 2. Roads 3. Curbs	1. Roads 2. Hazardous Waste 3. Sidewalks 4. Curbs	1. Sanitary & Combined Sewers 2. Roads	1. Transit 2. Roads 3. Storm Sewers 4. Sanitary & Combined Sewers 5. Sidewalks 6. Parks & Rec. Facilities	1. Transit 2. Roads 3. Curbs 4. Bridges

Most infrastructure facilities need some repair or are not acceptable. At the national level, only hazardous waste, water supply and parks and recreational facilities are in good or acceptable condition and all other facilities require some repair, or are not acceptable. Roads, bridges and sidewalks appear to be in the greatest need for repair at the national level. The results for all four population groups are summarized in Table 4.5, in a descending order of the response percentages. It should be noted that since the definition of an acceptable infrastructure facility was left to each respondent's judgment, what is deemed acceptable in one municipality may be considered unacceptable in another.

Table 4.5: Comparison of Present Condition of Infrastructure for all Population Groups (209)

Condition	General	Group 1	Group 2	Group 3	Group 4
Good/Acceptable	1. Hazardous Waste 2. Water Supply 3. Parks & Rec. Facilities	1. Transit 2. Community & Social Services 3. Bridges 4. Water Supply 5. Parks & Rec. 6. Sewage Treatment	1. Hazardous Waste 2. Community & Social Services 3. Transit 4. Water Supply 5. Solid Waste	1. Hazardous Waste 2. Solid Waste 3. Sewage Treatment 4. Water Supply	1. Hazardous Waste 2. Parks & Rec. 3. Storm Sewers 4. Water Supply
Needs Some Repair/ Not Acceptable	1. Roads 2. Bridges 3. Sidewalks 4. Curbs 5. Sanitary & Combined Sewers 6. Community & Social Services 7. Transit 8. Public Build. 9. Water Distribution 10. Sewage Treatment 11. Solid Waste 12. Storm Sewers	1. Roads 2. Sidewalks 3. Hazardous Waste 4. Curbs 5. Sanitary & Combined Sewers 6. Water Distribution 7. Solid Waste 8. Public Buildings 9. Storm Sewers	1. Roads 2. Sidewalks 3. Curbs 4. Sanitary & Combined Sewers 5. Water Distribution 6. Bridges 7. Storm Sewers 8. Public Buildings 9. Sewage Treatment 10. Parks & Rec. Facilities	1. Roads 2. Storm Sewers 3. Bridges 4. Sidewalks 5. Parks & Rec. 6. Sanitary & Combined Sewers 7. Curbs 8. Public Buildings 9. Water Distribution 10. Community & Social Services 11. Transit	1. Bridges 2. Community & Social Services 3. Roads 4. Transit 5. Curbs 6. Sidewalks 7. Sanitary & Combined Sewers 8. Sewage Treatment 9. Solid Waste 10. Public Buildings 11. Water Distribution

The cost of upgrading each of the infrastructure facilities to an acceptable level, is tabulated in dollars per capita in Table 4.6. Roads, water distribution facilities and sewers have the highest per capita average for the general case. As expected, the per capita cost for each population group is the highest for the first population group, at $ 4902/capita, and the lowest for the fourth population group at $1176/capita. This is due to the fact that the smaller municipalities have a small population base and therefore must incur high per capita costs to upgrade their infrastructure facilities to an acceptable level.

The total per capita cost to bring the infrastructure facilities surveyed, to an acceptable level, based on the responding population, was found to be $1484/capita, giving a total cost of $23.74 billion for the responding municipalities, and an estimated total cost of $43.94 billion for the whole country. However, this value must be taken in terms of the response rate for this question. This rate was low, due to the lack of information, ranging from 14% for hazardous waste to 63% for sanitary and combined sewerage, as shown in Table 4.6. It should be noted that the $44 billion required to upgrade Canada's infrastructure is a one shot deal. This amount would need to be spread over 10 or 15 years and the annual expenditure adjusted according to inflation.

Table 4.6: Average Cost to Upgrade Infrastructure Facilities for all Population Groups (209)

Facility	Average Cost	Population Responding
Roads	289	54%
Water Distribution	202	48%
Sewage	152	28%
Sanitary and combined sewers	146	63%
Public buildings	136	47%
Water supply	106	58%
Storm	103	49%
Transit	103	24%
Community and social services	60	27%
Parks recreational facilities	59	45%
Sidewalks	46	34%
Bridges	28	33%
Solid waste	27	24%
Curbs	21	26%
Hazardous waste	6	14%
TOTAL	**$ 1484**	

4.2.4 Transportation Systems

Many of the roads and highways built in the 1950s and 1960s have reached the end of their design life and require replacement (197). In the USCM-NLC survey, 25% of the respondents thought that their roads were in good condition, and the rest claimed that their roads need major repair, rehabilitation or replacement. Most of the cities gave top priority to the reconstruction of repair or roads and streets in their capital budgets (133).

Over one million miles of highway will need to be resurfaced by the year 2000 (235). According to the Federal Highway Administration, more than 70% of peak-hour travel on urban intestates occurs under congested or severely congested conditions (105). In addition, urban traffic congestion has increased drastically and more time is now spent commuting than ever before (189).

Transit systems in larger cities are aging, deteriorating, and undercapitalized. The average age of transit buses now exceeds recommended usable age by 20-35%. Between 20% and 30% of rail-transit facilities and maintenance yards are in poor condition (105). Systems in smaller cities are underused and overcapitalized. Politics and lifestyles and fewer incentives for using public transportation have left most transit systems underused. The National Council on Public Works Improvement found that the growth rate of transit vehicles is double the rate of increase in ridership and encouraging people to use public transportation is becoming increasingly difficult (164).

One of out of three bridges in the US is rated structurally deficient or functionally obsolete and needs major improvements ranging from deck replacements to complete reconstruction. According to the Federal Highway Administration, more than a quarter of all bridges are more than 50 years old (155). The US General Accounting Office concluded in 1991 that about 40% of the nation's bridges were deficient (152).

Finally, globalization of the airline industry will cause the number of enplanements to increase by 57% over the next decade. The number of severely congested major airports will grow from 7 to 17 if no new runways are added (105).

4.2.5 Waste Management Systems

More than 300 million tons of hazardous waste is generally created annually in the US. Total annual municipal solid waste will increase from 207 million to 218 million tons by the end of the century (105). The cost of adequate and safe facilities for solid waste is rising fast. In many cases, achieving higher levels of waste reduction is limited and public opposition to siting all types of facilities is also a major problem. There is very little progress in reducing hazardous wastes at the source and most of the effort is being directed towards controlling and dumping the end product (163).

4.2.6 Water Supply and Distribution

In the US, 756 urban water systems serve city populations of 50,000 or more (54% of the total population), 58,000 community systems serve smaller centers (30% of the total population), and another 15% of the population use their own wells while the remaining 1% have no piped water supply (133).

More than 10.000 dams are classified as high hazard in the US and 13,549 are classified as being of significant hazard (105). Leaking pipes cause some major cities to lose as much as 30% of their fresh water supply each day. Many communities cannot expand or accept more industrial or residential development because their wastewater treatment facilities are operating at or near full capacity.

Three major problems that have emerged are; deteriorated or inadequate distribution systems, a need for new sources of water supply, and inadequate treatment facilities. In many cities, leakage losses through cracked distribution mains and poor conduit joints have reached alarming amounts. Several US cities will require new supplies of potable water in the near future. In addition, only 97% of all community water systems met the Environmental Protection Agency's (EPA) standards for bacteria, while only 89% met the standards for turbidity. The USCM-NLC survey found that the condition of water supply and storage facilities was good in 75% of the cities that provided water (133).

Most water supply systems are facing problems due to water pricing below costs, inability to meet purity standards, or source contamination. In some places, the storage and distribution systems are deteriorating and in others, water supplies are limited (163). Age, underinvestment and underfunded state-administered inspection programs plague many US government regulated dams. Surveys conducted by the American Water Works Association suggest that breaks in water mains occur at annual rates of up to one for about every 6 km length line of pipe (192).

According to a survey conducted by the Ontario Sewer and Watermain Contractors Association (OSWCA), Ontario's watermains experience 25 breaks per 100 km per year, costing $40 million in repairs, and loss of 40% of purified water. This survey also concluded that Ontario's annual water repair budget was only 40% of the level needed. The organization indicated that 25% of the water system must be replaced and 50% of it must be restored over the next 60 years (31).

According to the US congressional Budget Office estimate, it would cost from $63 billion to $100 billion by the year 2000 to replace all the water mains older than 90 years and to rehabilitate others in the 756 systems in large cities (133). According to the EPA, annual compliance costs for water systems to meet the mandates of the Safe Drinking Act will reach $3 billion per year over the next two decades (105). It is estimated that the total annual revenues for all municipalities for water services provided is around $3 billion, and that up to $60 to $100 billion may be needed over the next 10 to 15 years to repair, extend and improve the infrastructure (32).

4.2.7 Sewers and Wastewater Treatment

Millions of Americans are not served by modern sewage treatment facilities. In 1980, 71% of the total US population was served by sewage collection systems, 99% of whom received some form of waste treatment in one of 18,000 municipal wastewater treatment plants. Almost 28% of the nations' sewers are combined sanitary and storm sewers, most of whom are located in the older, larger cities.

The three types of sewerage system problems faced by municipalities are leaking, blocked or undersized sewer pipes, undersize treatment facilities, and facilities which cannot handle storm water. Half of the respondents of the USCM-NLC survey claimed that their collection system and treatment facilities required major repair, rehabilitation, or replacement. In general, the municipalities surveyed placed storm sewers, sanitary sewers, and water treatment as their second, third and fourth priorities after streets and roads in their capital budgets (133).

Water quality has not been improving at the desired rate, despite considerable investment, due to the uncontrolled sources of pollution such as runoff from farmlands and roads. In addition, the overall productivity of secondary treatment facilities is declining (163). Wastewater treatment plants are also aging, deteriorating and being overused. The problems include (192):

- Potential release of inadequately treated water back into the environment;
- Raw sewage overflow onto waterways; and
- Ground-water contamination from leaking systems and septic tanks.

In a survey conducted in 1981, Environment Canada found that 22% of 52 municipal wastewater plants located throughout Canada, were considered to be overloaded and another 22% were operating at their design capacity. The Canadian Water and Wastewater Association estimated that, in 1984, the replacement value of municipal wastewater systems was $47.5 billion (31). Most of the problems being faced by the wastewater treatment plants lie with medium size and larger cities, where the older systems are in great need of extensive plant modifications, upgrading and additional sewer lines. Almost 75% of the plants have experienced water quality or public health problems and require some modernization or retrofitting. New demand and population increases will also require an additional 1,750 new plants in the US during the next two decades (192).

America faces at least a $137 billion wastewater infrastructure deficit due to the decay of old facilities, increased recognition of new water pollution treatment needs and population growth. Approximately 59% of the estimated clean water infrastructure needs over the next twenty years involve rehabilitation, replacement or construction of sewers, including combined sewer overflow corrections (235). In addition, it will take $137 billion to meet requirements of the Clean Water Act by the year 2012. By then, the US will need to increase the number of facilities providing wastewater treatment by 3,353 (105).

4.3 CAUSES OF DECLINE

Infrastructure in North America is facing obsolescence, which implies that the infrastructure does not measure up to current needs or expectations. In many cases, facilities that are obsolete continue to function at levels below the contemporary standards, and may not fulfill the function for which they were initially designed. Infrastructure designers and managers have largely neglected infrastructure obsolescence and its impact. They must be aware of the factors that cause obsolescence (152):

- Technological changes influence the scope or levels of services infrastructure is to provide:
- Regulatory changes impose new requirements on infrastructure;
- Economic and social changes in the markets within a region may alter the demands placed on infrastructure; and
- Changes in values or behavior of the people who use and own the infrastructure.

Despite the widespread attention given to this crisis, the remedies have been inefficient or they are of a temporary nature for the short term only. There are several reasons for this slow response to infrastructure renewal. A large volume of infrastructure facilities have deteriorated extensively and have outlived their useful life. They must be replaced immediately, which places very high financial demands on the cash-strapped local governments.

According to the 1995 McGill/FCM Survey, in general, funding shortages was cited by 92% of the respondents as the greatest impediment to improving the quality of the infrastructure. Table 4.7 summarizes the percentage for each of the six impediments: funding shortages, political inaction, prolonged public involvement, red tape, environmental assessment and lack of staff. Column "1" represents the greatest impediment, while column "6" represents the least impediment. Table 4.8 lists the 2 largest impediments for each population group. It can be seen that lack of staff was the second greatest impediment for the second and the third population groups. Political inaction ranked second for the first population group, while red tape ranked second for the fourth population group (209).

Table 4.7: Impediments for all Responding Municipalities (209)

Impediment	1	2	3	4	5	6
Funding Shortage	92%	7%	0%	1%	0%	0%
Political Inaction	5%	25%	21%	14%	15%	20%
Prolonged Public Involvement	1%	7%	21%	18%	22%	30%
Red tape	3%	13%	21%	26%	20%	17%
Environmental Assessment	1%	4%	31%	9%	34%	21%
Lack of Staff	8%	24%	17%	10%	13%	28%

Table 4.8: Impediments for each Population Group (209)

General	Group 1	Group 2	Group 3	Group 4
Funding shortage Lack of staff	Funding shortage Political inaction	Funding shortage Lack of staff	Funding shortage Lack of staff	Funding shortage Red tape

4.3.1 Funding Inadequacies

Most problems being faced by the infrastructure in Canada are caused by a lack of monetary investment in public works, resulting from reductions and elimination of federal and provincial/territorial financial assistance. Federal programs and contributions have always helped to ease the burden of financing major municipal public works. Between 1955 and the first half of the 1970s, the real annual expenditures on infrastructure by all orders of government tripled (87), but in the 70s and the early 80s, the federal assistance declined and all direct federal assistance for municipal infrastructure ceased in March 1984 (145). The elimination or reduction in federal and provincial grants have dramatically reduced the funds available for the maintenance, repair and replacement of the existing infrastructure facilities.

Rapid inflation in the 1970s was not matched by the rate of taxation, which left a lot of municipalities with less money at a time when they needed it the most for repairing and replacing infrastructure facilities. Another factor, that put a severe load on the municipal finances was that the municipalities were reluctant to borrow in the late 70s and the early 80s due to the high interest rates. It has become common practice now to defer maintenance and to reduce capital spending during fiscally stringent times. Funds set aside for capital purposes are often diverted to the operating budget to maintain existing service levels and to avoid deficits. The reduction in the availability of funds has put an enormous burden on the local governments to find alternative sources of revenue.

According to a report released by the House Committee on Public Works and Transportation (renamed the House Committee on Transportation and Infrastructure), federal spending on infrastructure has been declining. In 1965, infrastructure spending was 6.3% of the federal budget; by 1992, however, only 3.0% of total federal outlays were devoted to infrastructure. This under-investment in the nation's infrastructure threatens our national economy and quality of life (235).

In the United States, over the past decade, the public infrastructure stock has fallen continuously from nearly 55% of GDP in 1982 to less than 40% in 1992. Federal spending on new infrastructure fell from 1.15% of GDP in 1980 to 0.8% in 1993. Federal spending for capital investment is financed almost entirely from the discretionary category of the US government's budget, and caps have been placed on it for deficit reduction (105). Total public spending on infrastructure decreased from 5.6 per cent of the GNP (Gross National Product) in 1960 to 2.6 percent in 1985, and the annual infrastructure requirements range from US $45 to US $72 billion a year (163). Table 4.9 shows public investment in the infrastructure in various developed countries.

Table 4.9: Public Investment in Infrastructure (175)

	% GDP Invested		% Decrease	
Country	*1975*	*1980*	*1985/86*	*1975/86*
Germany	5.6	5.4	2.3	36
Canada	5.6	2.7	2.5	34
US	2.1	1.7	1.5	28
Japan	5.5	6.2	4.9	10
France	5.2	2.9	2.3	9

Figure 4.2 shows federal, state and local funding trends in the United States between 1960 and 1985. It can be noted that, measured in 1984 dollars, state and local capital investment peaked in 1972 at US $ 34 billion, and federal investment peaked at US$ 25 billion in the late 1970s (175).

Figure 4.3 shows a Canadian overview of the major expenditures by categories of infrastructure. It can be seen that during this period, $136.4 billion was spent on infrastructure, both new construction and repair and rehabilitation of the existing infrastructure. Over 50% of this amount was spent on roads and bridges, followed by 20% for electricity transmission and distribution lines, and about 10% for water supply systems. Sanitary systems and drainage networks incurred lesser expenditures (31). Figure 4.4 shows total expenditures on Canadian infrastructure by category between 1970 and 1988.

Figure 4.5 shows the pattern of spending on infrastructure by governments in 1988 for the following two categories of infrastructure (31):

- Water, sewage and drainage plants and networks; and
- Roads and bridges.

It can be noted that four-fifths of the spending in 1988 was incurred on new construction, and only 20% was spent on the repair of infrastructure. In addition, almost all of these expenditures were provincial or municipal, as the federal share was less than 4% of the total costs.

Figure 4.6 illustrates the history of spending on the six main categories of infrastructure: roads, electricity, water, sanitary sewers, storm sewers and gas. Most categories saw a slight increase from 1970 to the late 1970s, followed by a decline. However, Canada's population increased by about 27% from 1966 to 1986, and urban areas grew by 31% (31).

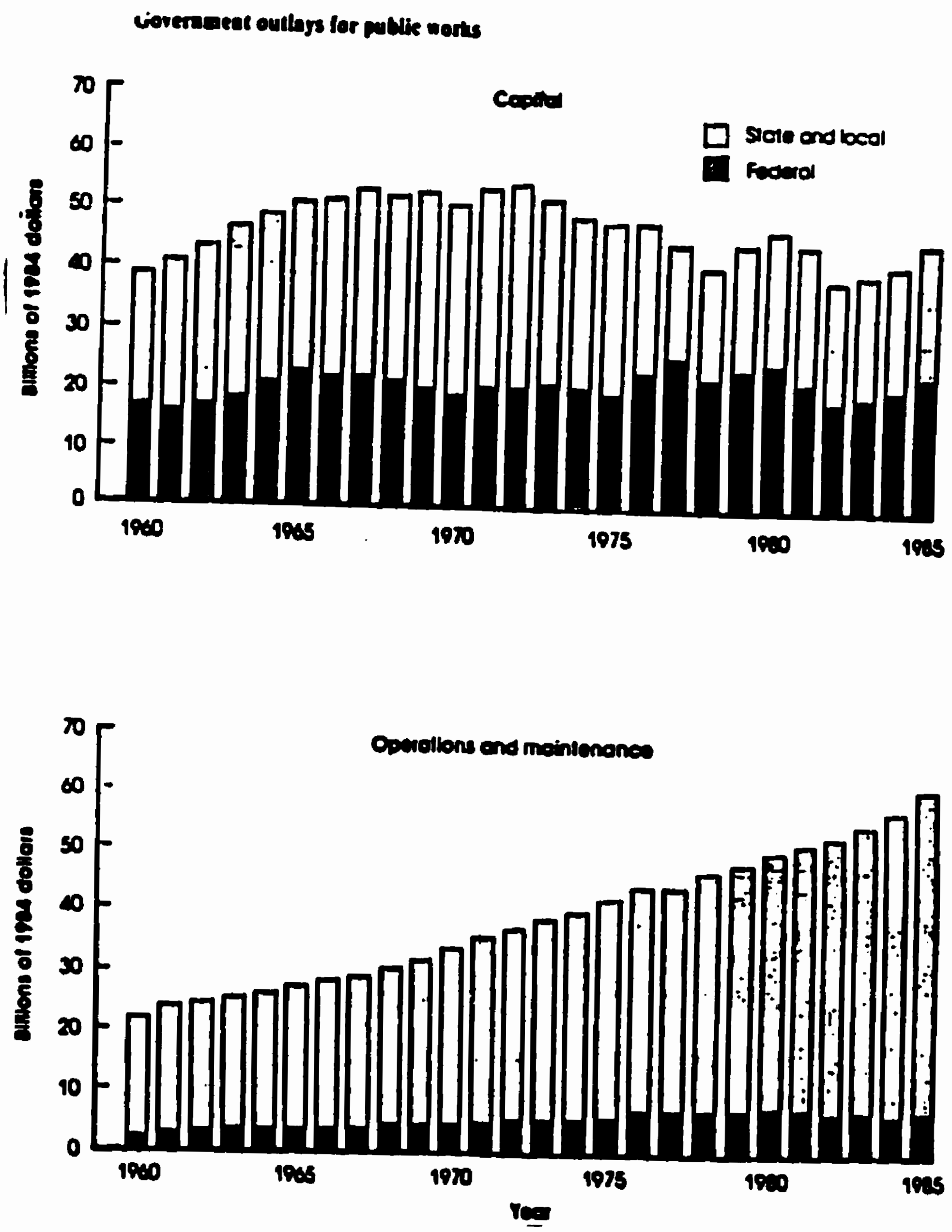


Figure 4.2 Government Investment for Public Works in the US (170)

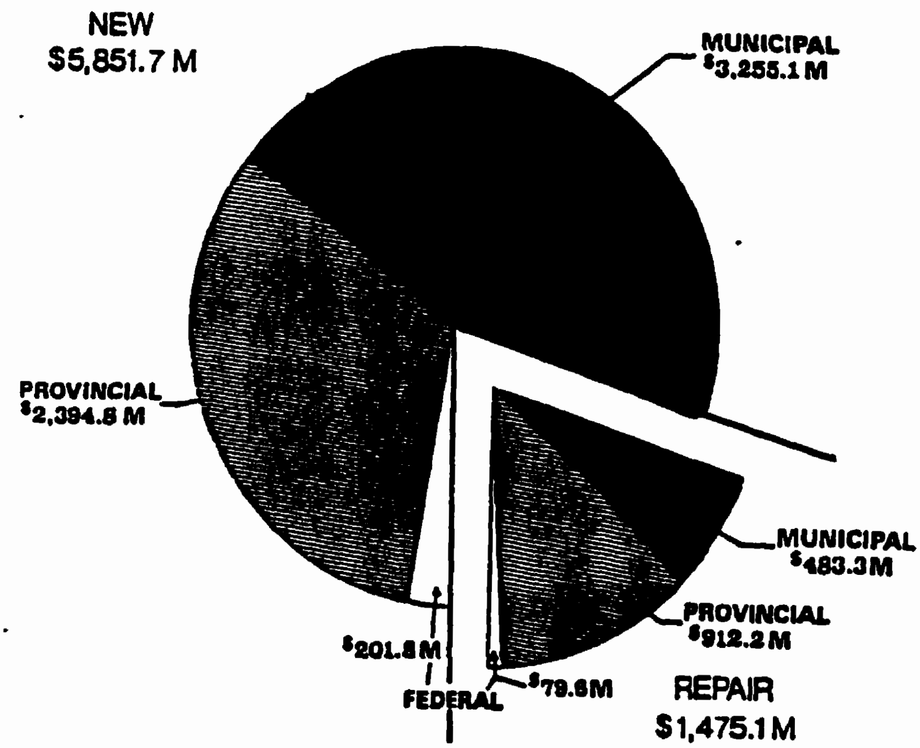
Category of Infrastructure	1970-88 millions of dollars	% of total	1988 millions of dollars	% of total
Highways, roads, streets	60 923.5	44.7%	5 073.0	45.0%
Parking lots	1 020.8	0.7	116.5	1.0
Sidewalks, paths	804.5	0.6	(in roads)	
Runways, landing fields, tarmacs	1 097.8	0.8	94.3	0.8
Bridges, trestles, culverts, overpasses, viaducts	7 106.5	5.2	573.8	5.1
Tunnels, subways	1 718.6	1.2	124.0	1.1
ROADS, BRIDGES GENERAL	72 671.8	53.3	5 981.6	53.1
Water mains, hydrants, & services	8 689.3	6.4	683.9	6.1
Water pumping stations, & filtration plants	4 213.4	3.1	444.8	3.9
Water storage tanks	449.5	0.3	56.4	0.5
WATER GENERAL	13 352.2	9.8	1 182.0	10.5
Tile drains, drainage ditches, storm sewers	7 272.8	5.3	560.0	5.0
Sewage systems, disposal plants, & connections	11 569.7	8.4	811.3	7.2
SEWERS & DRAINS GENERAL	18 842.5	13.8	1 371.3	12.2
Power transmission & distribution lines, trolley wires	26 156.5	19.2	2 334.5	20.7
Street lights	525.7	0.4	(in lines)	
ELECTRIC DISTRIBUTION	26 682.3	19.5	2 334.5	20.7
GAS MAINS AND SERVICES	4 874.7	3.6	390.1	3.5
TOTALS				
- **ALL INFRASTRUCTURE CONSTRUCTION**	136 423.5	100%	11 259.6	100%
- **ALL ENGINEERING CONSTRUCTION**	335 697.0		27 002.4	
- **ALL CONSTRUCTION**	849 943.6		85 279.0	

Figure 4.3 Pattern of Government Expenditures on Selected Infrastructure Items in Canada (31)

ACTUAL NATIONAL SPENDING ON INFRASTRUCTURE, 1970-88
(MILLIONS OF CONSTANT 1988 DOLLARS)

YEAR	ROADS	WATER	SEWERS STORMS	SEWERS SANITARY	ELECTRICITY	GAS	TOTAL LINEAR INFRASTRUCTURE	TOTAL CONSTRUCTION SPENDING	EXCL. INFRA	TOTAL ENGINEERING CONSTRUCTION	EXCL. INFRA
1970	5 012	552	275	794	1 936	433	9 002	45 785	36 783	18 880	9 879
1971	5 748	675	342	843	1 824	279	9 712	49 735	40 023	20 371	10 660
1972	5 680	657	429	1 034	1 633	298	9 730	51 302	41 572	20 657	10 927
1973	5 547	654	418	1 043	1 771	282	9 715	53 941	44 225	20 772	11 057
1974	5 340	808	470	1 146	1 648	317	9 728	55 490	45 762	21 231	11 503
1975	5 600	814	512	1 178	2 134	444	10 681	57 210	46 529	23 724	13 043
1976	5 361	972	560	1 258	1 931	263	10 344	63 227	52 884	24 159	13 816
1977	5 561	1 067	644	1 317	2 012	280	10 882	64 979	54 097	26 310	15 428
1978	5 811	1 288	723	1 041	2 395	286	11 545	64 620	53 075	26 999	15 454
1979	5 934	1 199	698	991	2 577	307	11 707	66 702	54 995	28 398	16 691
1980	5 855	1 146	697	918	2 349	346	11 311	66 842	55 531	30 134	18 823
1981	5 699	1 118	721	826	2 326	380	11 069	70 663	59 594	31 487	20 418
1982	5 616	1 127	592	870	2 381	417	11 002	64 666	53 664	31 398	20 396
1983	5 764	1 131	596	863	2 169	456	10 979	64 980	54 001	29 263	18 284
1984	5 547	1 076	584	773	2 070	531	10 580	63 424	52 844	28 210	17 629
1985	6 430	1 294	534	869	1 955	463	11 545	73 895	62 350	28 831	17 286
1986	6 281	1 112	645	793	2 000	462	11 294	76 932	65 638	26 045	14 751
1987	5 889	1 098	523	749	2 034	412	10 705	83 529	72 824	24 409	13 704
1988	5 981	1 182	560	811	2 335	390	11 260	85 279	74 019	27 002	15 743
MEAN	5 719	998	5 539	954	2 078	371	10 673	64 379	53 706	25 699	15 026
STD DEV.	314.4	224.6	122.7	167.6	258	79.3	749.1	10 453.6	9 900.3	3 825.8	3 213.5
STD/ MEAN	0.0550	0.2250	0.2214	0.1758	0.1242	0.2137	0.0702	0.1624	0.1843	0.1489	0.2139

Figure 4.4 National Spending on Infrastructure in Canada (31)



INFRASTRUCTURE EXPENDITURE BY TYPE ($000 s)

	NEW		REPAIR		
	Water, Sewage, Drainage	Roads, Bridges	Water, Sewage, Drainage	Roads, Bridges	Total
FEDERAL	85,366	116,420	26,532	53,060	281,378
PROVINCIAL	118,230	2,276,615	21,979	890,190	3,307,014
MUNICIPAL	1,808,394	1,446,714	206,305	277,044	3,738,457
TOTAL	2,011,990	3,839,749	254,816	1,220,294	7,326,849

Figure 4.5 Pattern of Canadian Government Expenditure on Water, Sewage, Drainage, Roads, and Bridges in 1988 (31).

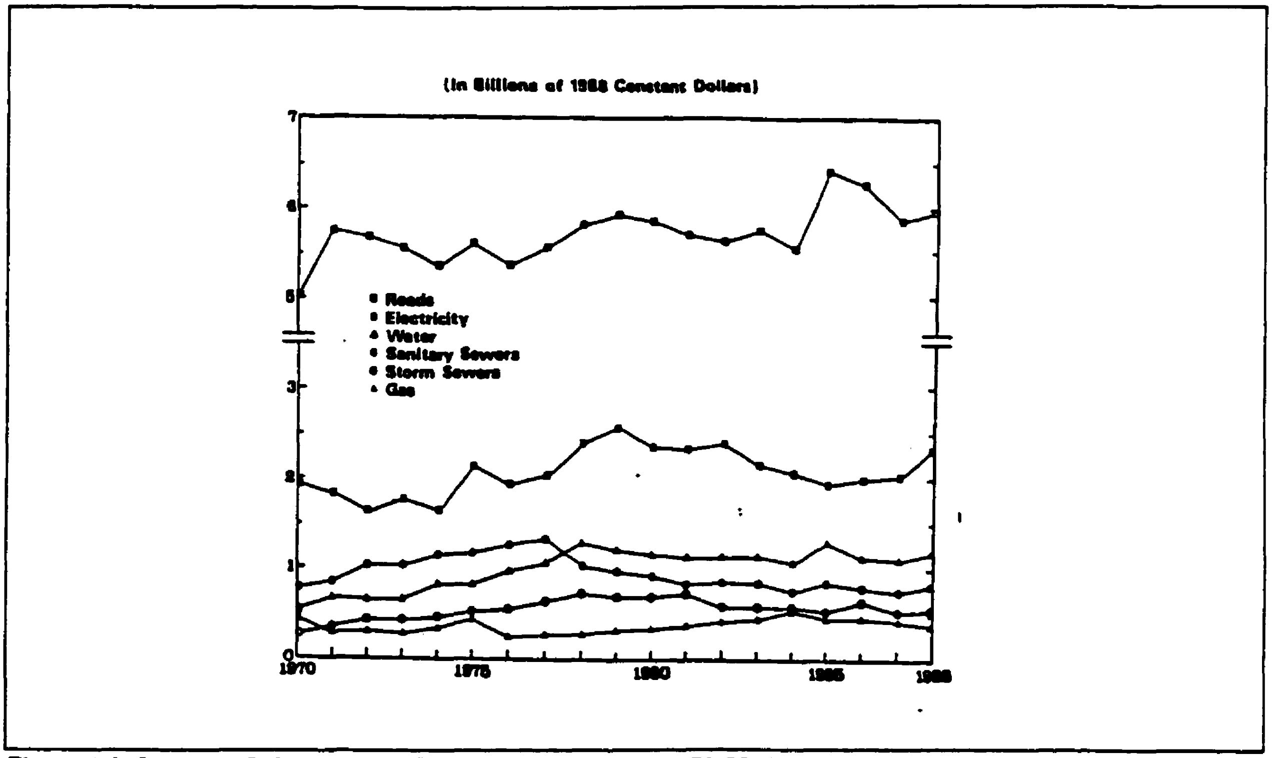


Figure 4.6 Canadian Infrastructure Expenditures by Type, 1970-88 (31)

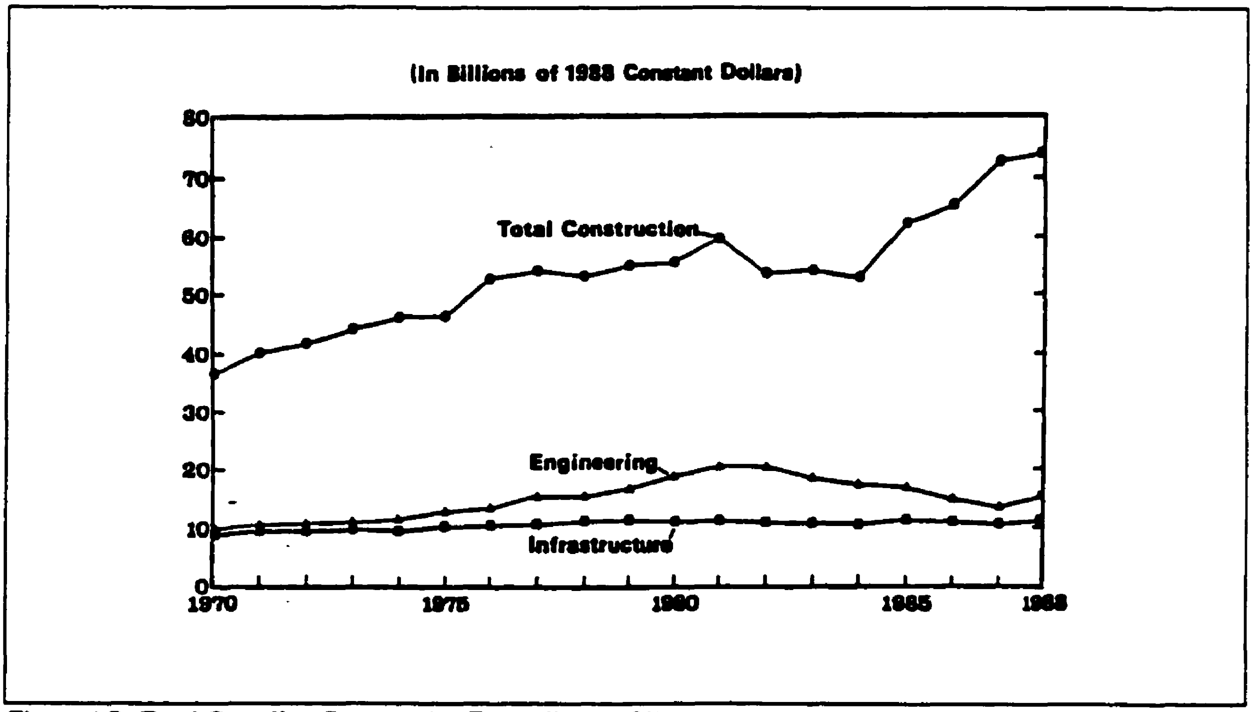


Figure 4.7 Total Canadian Construction Expenditures (31)

Figure 4.7 illustrates the infrastructure spending for the sum of the six individual categories shown in Figure 4.6. It can be concluded that spending on infrastructure has stagnated, while the spending on the other categories of construction have increased, which means that infrastructure is lagging behind the growth scene in the overall construction sector (31).

4.3.2 Government Priorities

One of the factors contributing to the infrastructure decay is the demand for public funds to build new infrastructure for new communities and economic development. This rapid growth has created an immediate need for new facilities. This practice of building new infrastructure facilities rather than the efficient use of existing ones, or the reconstruction of exiting ones, is endorsed by most local governments since this kind of public spending is more popular and politically acceptable. By catering to the needs of the population, local councils further compound the infrastructure decay problem by providing the rehabilitation and replacement of visible infrastructure rather than that of underground infrastructure. The general public is not fully aware of the current infrastructure crisis, and therefore it does not consider it a priority and would rather support the development of new facilities.

The rising needs for social, educational, housing, and public safety services have also diverted funds from public infrastructure. Again, critical programs such as health and police are more visible and have greater political appeal than the infrastructure needs. Social and public safety services directly affect large numbers of people and receive a much greater level of media attention and public support than the infrastructure facilities.

The increasing demand for infrastructure is also putting a lot of strain on the existing facilities. The US Department of Commerce estimated that industrial use of infrastructure will increase by 30 percent during this decade. Political inaction also affects infrastructure improvement. Local councils are generally responsive to the public, and therefore they may decide to put off decisions on projects that may adversely affect a small portion of the population. In addition, they are reluctant to borrow money when interest rates are high and also insist on not increasing municipal taxes to increase revenues (163).

Red tape and bureaucratic delay is an impediment to maintenance and reconstruction of infrastructure as well. The FCM found that many past federal programs, with their restrictions and conditions are examples of red tape and delay. In addition, provincial and local government regulations can also create delays (80). If public officials do not assign a higher priority to the current infrastructure crisis, the result will be rising costs, a decline in the quality of service, and further deterioration and loss of public confidence.

4.3.3 Lack of Information

In order to make a more accurate diagnosis of the infrastructure problem and to develop an effective strategy to solve it, when adequate information must be available on the status, location, capacity, performance, condition and maintenance costs of the existing infrastructure (163). Many local governments do not have mapping systems and inventory records to enable them to determine their infrastructure needs. Others simply do not have the information available and require a lot of time and effort to obtain it. In addition, the lack of staff in some small communities plays a major role in inadequate information retrieval systems and inability to analyze the available information (80). The lack of adequate infrastructure management systems was also identified as an impediment in the 1985 survey report.

4.3.4 Public Involvement

Prolonged public involvement in the decision making process is also a major impediment to the infrastructure improvement. Worthwhile projects get delayed unreasonably, or even canceled, by vocal minorities affected by the project. Delays make long-term planning very difficult for the municipal officials while simultaneously escalating the project costs. In addition, in the past two decades, the public is demanding elaborate and expensive facility treatments, which only makes infrastructure renewal even more expensive.

Most importantly, there is an increasing trend where more in-depth, cost/benefit analysis is being required to justify municipal expenditures. Although this causes further delay, it is essential for good financial management (80).

4.4 SUMMARY

Infrastructure in North America has become inadequate to sustain a stable and growing economy. Huge expenditures are needed to repair, rehabilitate, and replace our public facilities. If the deterioration of infrastructure is allowed to continue, local governments will suffer severe economic consequences. It is also known that the current revenues will not generate the capital necessary to renew and improve the infrastructure (32).

It was estimated in the eighties that it will cost US $ 1 trillion by the year 2000, and US $ 3 trillion in the next 20 years just to replace and repair the current US infrastructure. The McGill/FCM survey showed that an expenditure of $44 billion is needed to rehabilitate and renovate Canada's municipal infrastructure to an acceptable level within the near future. How could we have neglected our infrastructure to such as extent? How are we going to fund such huge investments?

If these renovations are left unattended for a longer period, say more than ten years, the existing deterioration of the infrastructure can be expected to escalate at an exponential rate. In another 25 or 30 years, the level of deterioration could be such that renovation or rehabilitation may not be possible and entire infrastructure facilities or major parts thereof may have to be replaced, all at a cost of several times the projected cost of $44 billion over the near future for Canada. This large sum which could be well over $250 billion, would constitute the third deficit faced by the Canadian citizens. In effect, out grand children and great grand children would end up assuming responsibility for this task of upgrading our infrastructure, basically due to lack of will on part of the various orders of government, business organizations and others to handle it now.

The existing literature suggests strongly that public spending on infrastructure generates growth in the private sector. Infrastructure renewal is necessary for maintaining and enhancing prosperity. The global economy makes infrastructure renewal necessary, if Canada is to compete in the international markets, since more than any other industrialized country, Canada depends on international trade for economic growth and prosperity. Around the World, governments in countries such as Germany, Japan and the U.S. are making enormous commitments to the infrastructure.

Why is it that individuals responsible for maintaining our infrastructure are not doing enough, if anything at all to rectify the present situation? It is beyond comprehension how civil engineers could have neglected the very facilities they helped develop and how they could have let the public officials put them in the back seat of politics dealing with infrastructure. Could this be due to neglect or lack of awareness of the problem? In addition, how could the very institutions (government) that instigated the development of infrastructure, also contribute to its deterioration through decreased funding, political inaction and changing priorities?

There is a lack of information on infrastructure for the Canadian scene. While the NRCC, the FCM and McGill University, have conducted some studies and research in this area, more detailed surveys and research on the condition of infrastructure, its needs, and total worth, need to be conducted.

Although several studies have been undertaken to determine the state of urban infrastructure in North America and its financial needs, they have not been sufficient in aiding public officials or city engineers take concrete actions. More studies need to be undertaken to determine the infrastructure needs and its current state of "health". It would also be very beneficial to have a complete inventory of the

North American Infrastructure. This would lead to needs assessment and condition assessment studies which are discussed in Chapter Six.

5.0 SUSTAINABLE DEVELOPMENT IN CIVIL ENGINEERING

5.1 INTRODUCTION

Civil engineers are in a good position to make contributions to a sustainable future due to their emphasis on environmental engineering and infrastructure systems. Sustainable development can be applied to most municipal infrastructure systems such as water, wastewater, transportation and solid waste facilities. Since our society is highly urbanized and prefers to live in high density areas, these facilities enable us to live in such an urban setting and at the same time raise our standards of living. However, as a society we have become heavily dependent on them and life without these facilities, which have now become an essential necessity, is quite inconceivable.

Since infrastructure facilities play a major role in urban development, they have a very significant impact on our environment.. After all, human settlements are "one of the most highly impacting forms of human activity on the environment," (66) and they are the major contributors to:

- Air pollution;
- Water pollution;
- Wastewater discharges;
- Spills and contamination;
- Soil contamination;
- Depletion of natural resources; and
- Loss of natural habitat.

New infrastructure systems must avoid unwanted side effects of both construction and use. For instance, as Bordogna pointed out, highway construction must not disturb environmentally sensitive areas and refuges. Roads of the future must be designed to avoid pollution caused by traffic jams, steep grades, and inefficient on-ramps, and provide biological corridors for the movement of migratory species. Materials must be salvaged and reused during construction of new systems, and new materials need to be environmentally friendly and recyclable (24).

In Canada, municipalities are still utilizing relatively conventional or traditional planning and development standards. These standards in use today were designed for periods of economic prosperity in the 1970's and 1980's. In the last several years, demand for standards that permit more compact, affordable, and innovative community design, has increased. "As we approach the beginning of a new century, we are witnessing a shift in values as a result of the changing economic expectations, a greater awareness of the limitations of government dependency on deficit financing, a deepening concern for long-term environmental sustainability. As social values and imperatives change, so also should the development standards." (161). In order to achieve cost efficiency and effectiveness, alternative development planning approaches have to be examined that demand innovation from architects, engineers and builders, and require compromise and flexibility in the municipal regulations.

Engineering and planning go hand in hand. They should be considered together where the goal is to create efficient and livable neighborhoods. This chapter discusses how civil engineering can contribute to the principles of sustainable development and adopt them in infrastructure planning and design, materials selection, construction, and planning.

5.2 INFRASTRUCTURE PLANNING AND DESIGN

Design is a process of identifying and solving problems, concerned with determining and employing the following forms (36):

- Buildings;
- Communities; and
- The landscape that shelters and supports human activity.

Engineers, architects and other professionals design facilities and systems to meet the needs and satisfy the demands that emanate from the social and economic activities. These activities and the resulting benefits determine the quality of our lives. Therefore, development is a means of improving the standard of living. The current generation is seeking global sustainable development to improve its lives, while assuring the future generations at least the same or better opportunities and improvements. Design has the most influence on engineering and construction in achieving sustainable development.

Within the design field, computerization, environmental consciousness and renovation/rehabilitation, can have the greatest impact for achieving sustainable development and are essential for the future productivity and effectiveness of design and designers. Challenges facing designers leading engineering and construction in achieving sustainable development are (36):

- Designing for sustainability;
- Using and advancing new tools and technology in design and construction;
- Practicing design in a global business environment; and
- Education and training for a new kind of designer.

Designers need to explore, evaluate, and refine options to reach decisions that are both feasible and likely to yield facilities compatible with their social, economic and environmental context. Designers need to assume a leadership role in promoting and identifying sustainable practices, and design the various infrastructure facilities following these practices. In addition, designers need to implement a design methodology that accounts for the entire facility life cycle.

Designers need to first develop an understanding of the basic concepts and principles of sustainable development and how these can be applied to the design of infrastructure facilities and buildings. They will have to formulate objectives and criteria for decision making in the design process, that will influence (36):

- Life cycle cost of facilities;
- Waste and pollution produced during the construction and operation of the facility; and
- The impact of these facilities on productivity of the activities they shelter and support.

During the design process, designers will have to ascertain that their decisions and designs would actually contribute to sustainability. This is not an easy task and will require the collection of technical, economic and cultural factors that can be used by designers and their clients to improve and adapt the design solutions and technology to local conditions. Managing such data can give rise to innovative technology and practices such as (36):

- Internationally standardized data-interchange formats and protocols;
- Sophisticated computer-based expert systems;
- International planning and design experience databases;
- Multi-media design encyclopedias and catalogs of details;
- Three dimensional space simulation software and audio-visual simulations; and
- Simplified three dimensional computer-aided design (CAD) systems with integrated analysis software.

Designers must also improve their personal skills, by learning to work increasingly in teams consisting of members from diverse fields, such as economics, political science, sociology, etc. and by making decisions in a multi-cultural setting. They will have to rely on effective communication among all of the participants in design and use sophisticated telecommunication systems and work in geographically distributed organizations.

Current infrastructure designers must explicitly consider obsolescence as a basis of making decisions. Infrastructure obsolescence and its costs are unavoidable as long as technological innovation and changing economic conditions continue. Obsolescence can play a valuable role in speeding up the introduction of new infrastructure technology into systems of long-lived facilities. Obsolescence allows new, more productive and less polluting infrastructure technology to be put into place, which might otherwise be blocked by long-lived facilities (152).

There are four strategies that may be pursued for delaying or mitigating obsolescence (152):

- Plan and design to provide the flexibility to respond to obsolescence-inducing change (target higher levels of optimum performance);
- Construct to assure that the facility does not fall short of the required characteristics of performance anticipated during planning and design (assure the targeted optimum performance is realized);
- Monitor change during operations and maintenance, and act to increase performance or slow its degradation, thereby deferring obsolescence; and
- Refurbish and retrofit early to accommodate change.

Facilities designed as finite systems, lacking flexibility to facilitate disruption free upgrading or expansion, would create higher levels of waste when modified. In the most extreme case, this inflexibility will result in demolition. Designers must note that since building materials and components have different life spans, the owners may not wish to replace them all simultaneously, but rather refurbish. Therefore, if a facility was originally designed with an inherent flexibility, refurbishment may prove to be an economically viable alternative to demolition and reconstruction ,thus reducing the amount of waste generated (54).

Such a design has many implications such as (54):

- Structural over-design may be required to accommodate potential expansion without the need for major structural modification;
- Physical distribution of servicing should allow for future upgrading and expansion though the use of oversized dedicated cores, eliminating the need for structural modification; and
- Detailing of elements, which may require upgrading, should allow removal and replacement without structural disturbances.

Although some infrastructure facilities do fail quickly, most endure for many decades, and sometimes for centuries. Their long service life is often considered one of their defining characteristics. It is important to note the difference in service life and physical life of infrastructure facilities. The physical life is the "actual" time it takes for the facility or one of its major subsystems or components to wear out or fail. The physical life comes to an end as some of its components exposed to the weather need replacing, mechanical equipment breaks down, metals corrode, etc., regardless of users' demands, economic factors, or technological advances (152).

Experience and testing are the two principle sources of information on which expectations of service life and design service lives, are based. Obstacles to predicting infrastructure service lives include:

- Our limited knowledge of the mechanisms of deterioration;
- Uncertainties of climate and other factors influencing deterioration;
- Lack of data; and
- Inherent complexities of the problem (which include the challenges of characterizing the service lifetime of whole facility or system, for instance, a bridge or a sewer network- as distinct from the lifetime of its repairable or replaceable components).

One of the most important questions facing designers is "How long should infrastructure last?" While these answers would be based mostly on individual judgment, experience, and values, typical answers would range from "several decades" to "indefinitely". Since the physical life of structures and materials are substantially longer, many infrastructure professionals argue that very long service lives should be presumed. Assuming a longer service life helps to justify higher initial facility development costs, since benefits accrue over longer time periods (152).

5.3 MATERIALS

The availability of appropriate materials is crucial to realizing the goal of sustainable development. New materials and systems would facilitate construction, design for durability, demolition, reuse and have direct benefits for life-cycle improvements throughout the world. If conventional materials are used to repair, rebuild and expand current infrastructure facilities, the result will be prematurely obsolete structures. Table 5.1 lists the traditional and sustainable criteria for building materials. If infrastructure facilities are not designed to minimize life cycle costs with regard to both the financial and environmental impact requirements, they would become a major burden for both industrialized and developing nations (36). This would naturally require more information on the potential recyclability and associated health and safety impact of the different waste materials and by-products in asphalt pavements (43).

Table 5.1: Traditional and Sustainability Criteria for Building Materials, Products and Systems (144)

Traditional Criteria	Sustainability Criteria
• Performance • Quality • Cost	• Resource depletion • Environmental degradation • Healthy environment

When trying to select a materiel for a facility, such as wood or steel, the following technical criteria can be applied to ensure sustainable practice (144):

- **Embodied Energy Content:** A quantification of the amount of energy needed to extract resources, manufacture products, install them into buildings, and transport them between the different phases.
- **Greenhouse Warming Gases:** This criterion determines the quantity of greenhouse gases such as carbon dioxide and methane, emitted in the production of materials, with the implicit assumption that fossil fuels are the energy sources.
- **Toxic Generated /Content:** This criterion assumes that fossil fueled energy systems will be used, resulting in the presumed generation of sulfur and nitrous dioxides and other substances.

5.3.1 Reuse of Secondary Materials in the Housing and Utility Building Sector

In order to achieve sustainability in the design and construction industry, civil engineers must renew and recycle materials. However, not enough is being done. Some examples of recycling include milled asphalt paving material being recycled into hot-mix asphalt paving mixtures. Recycled asphalt pavement (RAP) can be recycled into hot mixes, cold mixes, or in-place mixes. It can be used in highways as in unbound aggregate base and subbase, stabilized base course, shoulder aggregates, and open-graded drainage courses. In addition, approximately 2.9 million tons of reclaimed concrete are being recycled annually. Recycled coarse aggregate is more suitable than recycled fine aggregate when reused in concrete mixes. RCP is also useful as an unbound base course aggregate, in cement-treated base, as an asphalt paving aggregate, as embankment base material, and as riprap (43).

Building Design

The main impediment to broader reuse of secondary materials in housing and buildings is high costs. To improve the current situation, the following approaches for the building construction approach are recommended to insure that buildings will be designed considering life cycle costs (36):

- The client or user draws up a set of specifications with the architect providing advice on the possibilities of durable construction.
- The architect works with a demolition consultant during the design phase.
- The demolition expert evaluates the design for the building in terms of its demolition at the end of service life and the costs involved.
- Any detrimental external environmental effects, during the building's life cycle and in the following period are taken into account.
- A database of life cycle analyses for most of the building materials and elements is developed.
- Free-style construction would be widely used where the supporting structure, shell and interior elements will be designed separately.

The supporting structure, interior elements and shell erected from separate elements would be connected by means of dry construction techniques. This would make it possible to dismantle the building without damaging the building elements. The building elements can also be reused, besides simplification of repairs and renovations involved.

Construction of Housing and Utility Buildings

- In the commissioning and design stage, the construction techniques and methods are finalized.
- These decisions are executed in the construction stage.
- Construction is the assemblage of detachable building elements delivered to size resulting in very little building waste.
- The suppliers of building materials take care of assemblage at the building site and focus on the production of composite building elements for the supporting structure, shell, interior elements and fittings.

Logbook and Environmental Levy

The owner of each completed building (including private homeowner), should be obliged to keep a logbook on management and use, and update it on a regular basis. This logbook would consist of the original specifications for all the materials and building elements used and all subsequent modifications during reparation and renovation. The logbook would assist in selecting the most suitable techniques for renovation, or demolition. When the building is sold, the environmental costs of demolition and disassembly at the end of the technical life span is taken into account and subtracted from the selling price.

Repair and Renovation

- A lot of progress needs to be made in the techniques used to repair and maintain buildings.
- Widespread use of technologies combating the corrosion of steel reinforcement in concrete is required.
- The demolition and replacement of concrete elements is difficult and expensive. New techniques to overcome these problems are needed.
- Renovation waste must be limited.

Reuse of Old Building Stock

- Owners and users need to seriously consider the pros and cons of demolition and new construction against the reuse of existing structures.
- The statutory environmental levies on the demolition cost must be taken into consideration since this would involve much increased demolition costs, and reuse of the various dismantled elements may then prove cheaper than constructing a new building.

Demolition and Recycling of Complete Building Elements and Building Materials

Separation at source and selective demolition will need to become compulsory by:

- Banning dumping; and
- Setting high acceptance charges for unsorted building and demolition waste;

The demolition of certain buildings will not be avoidable. Here the emphasis would need to be on recovering recyclable building materials. The salvaged materials would be put to durable reuse or temporary storage. The recycling and demolition of building materials may mean the end of extraction of primary materials such as gravel, marl, and sand, in many countries.

5.4 CONSTRUCTION

Current construction operations are unsustainable since they consume energy, create noise, and produce waste. It is crucial for us to change the way we practice construction today in order to protect the environment. Sustainable development requires the revision of current construction practices and a clear understanding of the issues involved. Those involved in the construction industry can no longer continue using their old ways. But first they must understand the issues of sustainable construction as listed in Table 5.2.

Table 5.2: Issues of Sustainable Construction

Resources	• Energy consumption • Water use • Land use • Materials use
Healthy Environment	• Indoor environmental quality • Exterior environmental quality
Design	• Building design • Community design
Environmental Effects	• Construction operations • Life cycle operations • Deconstruction

Kibert lists six principles of sustainable construction (144):

- **Conserve:** Minimizing resource consumption would force us to use high efficiency systems and use of durable materials that have long lifetimes and requiring low maintenance.
- **Reuse:** Maximizing resource reuse means that we are using resources that have already been extracted and require minimal processing.
- **Renew/Recycle:** Renewable or recyclable resources must have priority over other resources.

- **Protect Nature:** Since building new facilities impacts the natural environment, we need to consider restoring along with sustaining it.
- **Non-Toxic:** Toxic materials must be handled with care and eliminated where possible.
- **Quality:** This includes the excellence of design, selection of materials, and construction practices.

Reducing project delivery time is crucial in making the construction process more efficient and sustainable. Environment permitting, zoning approvals and other regulatory approvals are one of the biggest obstacles to be overcome by contractors and play a major role in increasing the project delivery time (time including the inception of the project to its completion). However, they are not under the construction industry's control and only the government can take action in making these processes less time-consuming. Therefore, contractors must look elsewhere for reducing their project delivery time.

A lot can be achieved by making major organizational changes and increased use of the design construct approach which would improve the constructability of designs by designers and decrease the constant design changes by owners. This means that facilities must be designed for constructability and designers should have sufficient knowledge of construction methods and processes and allow construction engineers to participate early in the design process. In addition, increased use of information technology (databases, CAD, and electronic transmission of design data) can also reduce project delivery time considerably.

Projects costs accumulate over the entire project life cycle: design, construction, operation, maintenance, renovation and eventual removal. Technologies supporting reductions in project costs include (36):

- Simulation techniques and data for life cycle performance and costs;
- Knowledge-based systems for project design, construction planning, management and operations and maintenance;
- High performance (constructability, functionality, environmental sustainability, durability and maintainability) materials, components and systems;
- Construction personnel and equipment capable of placing materials and components efficiently and correctly to assure quality.

Improving the quality of the completed project is another important part of the construction process that needs to be addressed. Project quality includes functionality of the facility, the health and safety of the users and neighbors, efficiency and environmental quality. The major contributors to the lack of quality in the constructed project are:

- Design quality; and
- Management and supervision of the project.

The other minor contributors are labor capabilities, material and equipment quality and changes by owners. Technologies for improving project quality include (36):

- Information and decision support systems;
- Automation in techniques;
- High performance construction materials; and
- Performance standards and conformity assessment mechanisms.

Finally, the project should have as little environmental impact as possible. This can be used for the owner's benefit since life cycle performance attention to environmental impacts can:

- Speed regulatory approvals for the project;
- Avoid high fees for disposing construction wastes and claims of environmental damage to neighbors;
- Reduce operating costs for energy and environmental control measures;
- Provide a healthy and productive environment for users and neighbors of the facility; and
- Reduce environmental protection costs in renovation and removal.

Since modern construction is very energy intensive and produces large volumes of waste, sustainability can be introduced into the process by structuring contracts to introduce sustainability indicators. The following components should form part of such a document (102):

- Reduce construction project scope by specifying environmentally friendly design which considers reducing the size of the project, minimizing the energy requirements and designing for deconstruction/reuse/recycle; and
- Specifies environmentally friendly construction by specifying the 3Rs, and an effective project management which includes the adoption of partnering principles and open communication of sustainability objectives.

5.4.1 Construction and Demolition Waste Reduction

It is estimated that at least 20 to 30 million tons per year of construction and demolition (C&D) waste are generated in the US alone. This waste consists of wood, plaster, concrete, glass, metal, brick, shingle, and asphalt. Portions that are reclaimed, crushed, and processed into aggregate are concrete, bricks, glass and old asphalt (43). This is a serious problem and an obstacle for achieving a sustainable future. The engineer should realize that deconstruction or demolition of facilities should actually result in materials for new construction. Table 5.3 lists C&D waste as percentage of all solid waste entering landfills and Table 5.4 lists the main causes of construction waste found by Gavilan and Bernold and Craven (26).

Table 5.3: C&D Waste as Percentage of all Solid Waste Entering Landfills in Various Countries (26)

Country	C&D Waste (by weight) (%)
Australia	20-30
Finland	13-15
Germany	19
Holland	26
United States	20-29

Table 5.4: Sources and Causes of Construction Waste (26)

Source	Cause
Design	Error in contract documents Contract documents incomplete at commencement of construction Changes to design
Procurement	Ordering error, over-ordering, under-ordering, etc. Suppliers error
Materials handling	Damaged during transportation to site/on site Inappropriate storage leading to damage or deterioration
Operation	Error by tradesperson or laborer Equipment malfunction Inclement weather Accidents Damage caused by subsequent trades Use of incorrect materiel requiring replacement
Residual	Waste from application process Packaging
Other	Criminal waste due to damage or theft Lack of on site materials control and waste management plans

The C&D waste consists of materials produced during construction that is not incorporated directly or indirectly into the finished product. The waste generated at demolition projects depends on whether the primary construction is masonry or wood. The portion of the waste that can be reused varies according to the presence of specialized equipment. It has been pointed out that a strong commitment to the 3Rs can yield reuse and recycling rates that exceed 94% (103).

Canadians are among the largest consumers of energy and generators of waste. About 16 millions tons of solid waste is produced every year, 30% of which is construction and demolition (C&D) waste, which is virtually all recyclable. Canadian produce about 1.5 kg of waste per capita daily.

When trying to determine the applicability of reuse vs. recycling for a given material, it is useful to study the concept of embodied energy of a material. Figure 5.1 demonstrates the embodied energy of some construction materials. The embodied energy consists of:

- **Energy intensity:** required to produce a unit quantity of material; and
- **Installation Energy:** required to install a unit quantity of material.

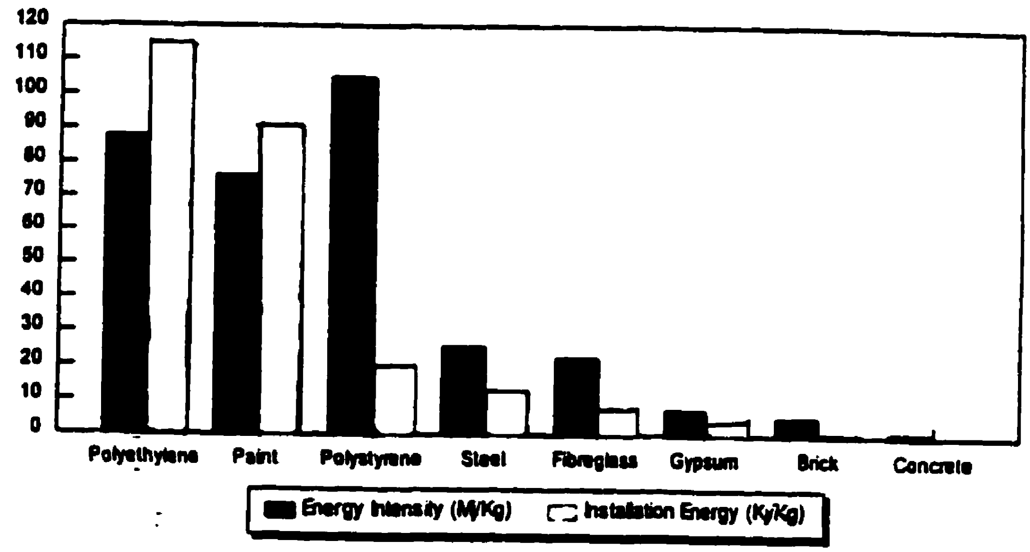


Figure 5.1 Embodied Energy Requirements of some Construction Materials. (103)

Embodied energy can then be used to determine the 3R hierarchy of a given material.

- **Reduce:** This requires very low energy inputs to achieve high diversion.
- **Reuse:** This can be applied to materials that have high installation energy and low energy intensity.
- **Recycle:** This is appropriate for materials with high energy intensity and low installation energy.

It should be noted that the energy intensities of materials are much higher than the installation energy required. The order of precedence for the 3Rs is based on the energy consumption. One should reuse manufactured materials and synthetics whenever possible and recycle the balance of the materials. It has been demonstrated that approximately 86% of materials are recyclable and 14% are reusable. (103)

Aside from achieving sustainability, the 3Rs should also be practiced for cost effectiveness reasons (103):

- Landfill diversion rates of up to 75% have been noted;
- Tipping fees have risen 600% in the last three years;
- Surcharging of 50% to 100% on recyclable materials is common;
- Increasing trend of banning receipt of recyclable materials at landfills.

Reduction strategies for C&D waste are:

- **Pre-Design Phase:**
  - Is the project really necessary?
  - Can energy/construction requirements be met in a sustainable manner??
    - Analyze project layout to reduce its size and cost;
    - Use the existing infrastructure efficiently; and
    - Minimize embodied energy of components.
- **Design Phase:**
  - Try to use recyclable and recycled components as much as possible;
  - Perform life cycle costing; and
  - Design towards maximum energy efficiency.
- **Construction Phase:**
  - Implement the 3R strategies; and
  - Practice efficient materials management.

The following actions are relevant to the demolition specifications:

- Identify materials to be separated;
- Compile database of receiving facilities;
- Segregate materials that can be reused; and
- Divert balance to recycling facilities.

The following specifications can lead to increased reuse of materials and components:

- Compile schedule of materials amenable to reuse;
- Stockpile, inventory and redirect reuse items to approved reuse facilities;
- Select the reuse facility that yields the maximum social benefit; and
- Capitalize on needs awareness.

Recycling of materials and components can be maximized by the following actions:

- Choose materials categories carefully; and
- Specify handling/separation process.

5.5 LIFE-CYCLE ASSESSMENT

The engineering assessment of life cycle costs considers performance and cost factors over the operational lifetime of any infrastructure system or facility which consists of the following phases (36):

- Design and construction;
- Maintenance and repair;
- Replacement;
- Energy costs minus the salvage value accrued to demolition and disposal; and
- All other costs to the society due to restricted or complete use of the infrastructure system of facility.

Life-cycle costing (LCC) is a future-oriented method using many parameters such as future costs, future incomes, the analysis period, the useful life, the discount rate, the rate of inflation, etc. It is a technique that permits the appraisal of the owning and operating costs of a facility over a selected life cycle or estimated useful life. LCC is a progression through the phases of design, construction, and maintenance, including renewal as the project undergoes changes over time. LCC is not a new concept. Its principles are based upon economic theories that have been used in investment appraisal in industrial and commercial activities. In civil engineering, LCC can be used in the following three stages of the construction process (7):

- Planning and design;
- Construction; and
- Maintenance.

To bring sustainability into the materials selection process, environmental and other costs associated with the choice of materials will have to be included. The environmental costs would be an accounting of impacts associated with the health, safety and productivity of occupants or users.

Currently, decisions concerning design, construction, maintenance and improvement of a system are mostly based on evaluation of the initial costs rather than on the total lifetime costs for the system as a whole. There should be methodologies for incorporating life cycle considerations into the planning and engineering process as well as the building codes and the competitive bidding processes considering all life cycle costs.

The decision making process should now adopt a long term view and it must consider all life cycle costs instead of the initial costs only. To achieve sustainability, the needs of future generations would have to be considered through an accounting of the complete life cycle impacts of the various alternatives.

5.5.1 LCC Analysis for Public Works

Due to the limited amounts of funds being available to the public agencies and the political pressure to produce short-term results, traditionally, the approach to construction costs has been basically on the initial cost of the project design and construction. Historically, owners of facilities consider direct costs and regulatory requirements, and ignore other considerations such as renewability, recyclability and reuse, energy consumption, operating cost, waste and pollution reduction, and risk and liability. All these should be incorporated into their decision making process (38). Facility owners are now becoming more aware of the fact that the true cost of construction installation does not end with completion of the construction of the facility. Owning and operation costs are comprised of the following (7):

- Initial cost;
- Operating costs;
- Energy costs; and
- Maintenance costs.

Planning and Design

It is during the earliest stages of a project that the greatest savings potential for a LCC analysis occur. The potential savings are more significant and the costs of making changes in the plans and specifications are much less.

For some cost elements, it may be more useful to use good judgment over precise calculations. Good judgment can be applied to interest rates, useful life, and inflation rates. Precise calculations will come handy for the elements of energy consumption, operating efficiencies, and total hours of operation. Interest rates need to be predicted as accurately as possible. Sensitivity analysis should be applied to decrease the impact of estimating errors.

During an LCC analysis, all future cash flows for all alternatives under consideration are estimated. Then, figures are discounted to a present value and added to the initial cost estimate for direct comparison and selection. LCC expenditures can also be compared on an annual-equivalent basis (7).

The systems showing the lowest LCC will usually be the first choice if all other performance requirements are met. However, this may not be the case when the following are taken into consideration (7):

- Delivery time;
- Pollution effects;
- Aesthetic considerations;
- Maintability; and
- Owner preference.

Construction

The purchasing departments of both contractors and construction facility owners can see great benefits by applying LCC as part of the standard procurement procedure. Life expectancy of products can be considerably lengthened by selection application of LCC.

Tender documents could include instructions to the contractors to submit alternative methods, components and materials which if incorporated would result in an overall life cycle saving. This would however, require bids to be analyzed in a more detailed manner than those based on the first cost only. Actually, to be more effective, the concept of lowest initial bid should be modified. Due to the current system, suppliers produce components and systems which ensure the lowest initial cost, ignoring the running costs once the system is in place and operation. In order to practice LCC in the procurement process, specifications should put more emphasis on performance to allow specialist suppliers to submit alternative suggestions to meet the required performance at the lowest total cost. Finally, bids should be compared on the basis of their LCC analysis and not their initial costs (7).

Maintenance

Generally, maintenance of a constructed facility is not uniform during its life, rather it increases with age, or it shows a variation consistent with the utilization of the facility. The costs of maintenance and the incidents of plant equipment breakdown increase with age.

It is very important to decide when to dispose of and replace an element, or envelope of the facility itself since it may cost more to maintain than to replace. If the running costs after the change along with the equivalent annual costs of making change are less than the annual running costs if no changes were made at all, then the component of the facility should be replaced. If the renewal of a component provides additional benefits, such as reducing expenditures, the value of benefits should be incorporated into the calculations (7).

5.6 ALTERNATIVE MUNICIPAL STANDARDS FOR INFRASTRUCTURE

Municipal standards are the development requirements set by municipalities for services such as sidewalks, curbs and sewers. They differ from one municipality to another and constitute a major portion of their capital and operations budget.

In general, the road right-of-way width in most new subdivision is very wide; local streets are designed to discourage all but local traffic. This wide right-of-way width ensures a wider pavement, and adequate space for the various underground utilities located in their own private trench. On-street parking is totally discouraged which translates into a compulsory garage and a larger setback. Curbs and sewers are required rather than ditches and drainage swales. Finally, sidewalks are required on both sides of the street.

Innovations can help reduce the cost of housing and at the same time reduce the financial burden of the municipalities. Until today, municipalities have set municipal standards that are in most cases costly and at the same time unnecessary. The maximum level of service need not be provided in all parts of the municipalities and in most cases one can do well with the minimum requirements. However, caution needs to be exercised when trying to provide the minimum level of service and in some cases cutting the service all together. After all, a reduced level of service in some cases can lead to higher maintenance costs, and therefore savings at the initial stage (capital costs) may not be feasible and may just prove more costly in the long run. The standards discussed in the following sections are those researched by private institutions and municipalities. They refer to minimum standards that can be set, but are not applicable to all municipalities. It is up to the municipality to decide which alternative standards are appropriate for their particular case.

We must be careful with implementing alternative municipal standards for infrastructure and ensure that the quality of the infrastructure built does not decline in order to gain housing affordability. Infrastructure efficiency should not undermine infrastructure quality.

5.6.1 Strategies for Infrastructure Efficiency and Housing Affordability

Lot Dimensions

Single family housing emerged as the predominant form of housing in the 1970s and 1980s. The economic prosperity of these two decades resulted in increased house sizes due to increased expectations of a consumer society. Large houses occupy large lots, and although builders have responded to the high cost of serviced land by building big houses on smaller lots, lots still remain quite large. The increase in the size of the average new house, and the level of amenities it contains, have increased the cost of housing accordingly. As the cost of serviced land increases further, there will be a higher demand for smaller units on smaller lots.

Reducing the lot width is the single most important variable in reducing infrastructure costs since the length of all services is reduced. Affordable housing can be encouraged by reducing the lot area, and frontage and setback requirements, which would increase the yield and distribute the cost of land across a larger number of units. The Regional Working Committee on Alternative Urban Development Standards (The Technical Committee) in Ottawa agreed on the feasibility of a lot dimension of 7.9 m of frontage by 23 m in depth for a single and a lot dimension of 5.5 m by 23 m for a street townhouse. These lots assume a house length of 11 m, a rear yard setback of 6 m, a front yard setback of 3 m, and sideyard setbacks of 1.2 m.

Building downsized singles on smaller lots would cater to the market for new single-detached housing with the advantages of privacy and outdoor space at an affordable prices. The houses would be sited so that the driveways would be twinned to allow landscape space for the placement of things like transformers and hydrants, snow storage, and parking on one side of the street.

The streetscape can be improved through the use of zero-lot-line siting or clustered plans. The units have to be designed carefully and sited on small lots in order to provide the level of privacy and the usable open space found in detached homes. The effective design of small lot developments would become the challenge of future planners.

House Setbacks

Setbacks play a role in determining the face-to-face distance between the houses. They provide parking space in front of the garage, privacy from the street, and an aesthetic streetscape. Houses are usually set back by 6 meters. However, in order to provide parking space, only the garage needs to be setback, instead of the whole house. This setback should be measured from real barriers like sidewalks or curbs, instead of the property line, which in practice does not really exist (161).

Sidewalks

Sidewalk requirements should be determined at the very beginning of the planning process and at the latest be set at the draft approval stage. Fewer sidewalks can save land and construction maintenance costs.

Instead of being given an exclusive location within the road right of way (R.O.W.), sidewalks should be placed right on top of the utilities. The utilities are rarely dug up after a subdivision is developed and even if they are, the cost of replacing the sidewalks are marginal compared to the cost of separating sidewalks and utilities.

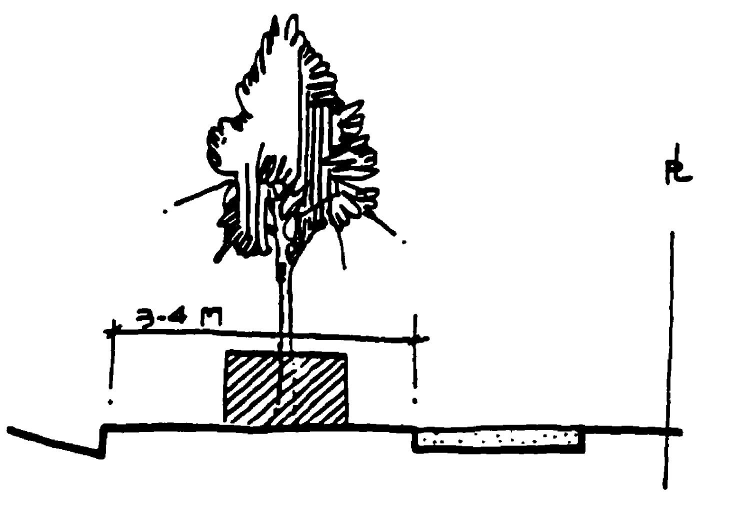


Figure 5.2 Standard Sidewalk Location (162)

There is a great advantage in moving the sidewalks closer to the curbs. A cost effective approach is to construct the sidewalks at the curb line, and providing extra width to allow for storage of snow in the gutter and on the edge of the sidewalk on an as needed basis. Once or twice per winter, this snow would be removed by the municipality.

Moving sidewalks closer to the curb, or eliminating them, will allow a reduced setback for the garage and thus a reduced lot depth. If the sidewalks are eliminated and if the setbacks are measured from the sidewalk, instead of being measured from the property line, and if the maximum coverage limits are reduced, it would not really be necessary to reduce the R.O.W. width to achieve more compact housing.

Until recently, sidewalks have been located as far as practical from the curb within the right-of-way. This in turn has created a separation of 3 to 4 m between the curb and the sidewalk as shown in Figure 5.2. However, sidewalks should be moved closer to the curb to reduce the R.O.W. Setting them 1.5 m from the curb would provide sufficient space for snow storage in most instances. In areas of high snowfall, the setback suggested in figure 5.3 should be increased.

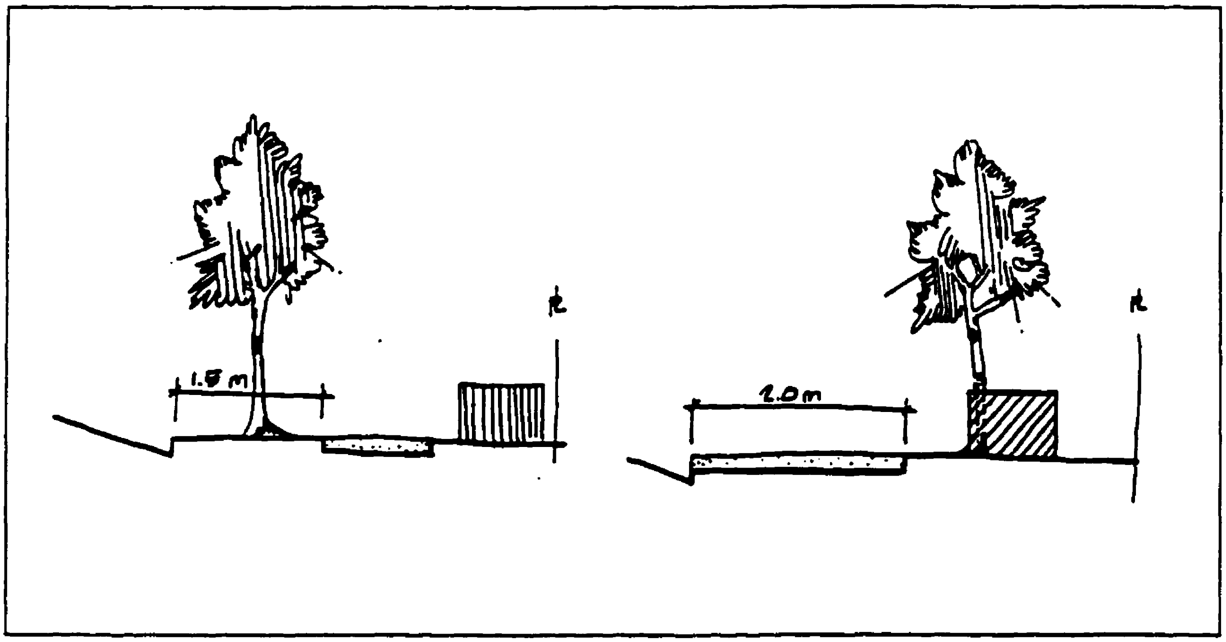


Figure 5.3 Alternative Sidewalk Locations (162)

Services Under Sidewalks

In most places, nothing is constructed under the sidewalks, so that in case utilities require repair or replacement, the sidewalks would have to be removed. If the cable utilities are constructed under the sidewalks, they are installed in concrete-encased duct banks with manholes.

It is recommended that where compact streets are required, the services should be constructed under the sidewalk. The advantages of this are (238):

- Protection of the utility from third party damages; and
- Reduction of the R.O.W (right of way).

Therefore, services should be installed before the sidewalks, which is achievable because the sidewalks are usually installed after the houses are constructed. As the Ontario Hydro authorities endorse only hydro cables encased in concrete duct banks under the sidewalks for reasons of economy, directly-buried PVC ducts should be considered as an alternative.

Curbs

Savings can be achieved in this area by using rolled curbs in an urban development project. However, even greater savings can be achieved by eliminating the use of curbs altogether. The potential savings were estimated to be approximately $70.00 per linear meter of the roadway (197).

Along with reducing the capital cost of development and the associated on-going maintenance costs, the elimination of curbs also allows the runoff to percolate through the grass and thus reduce the amount of storm runoff and contamination of effluents. The groundwater recharge would also increase.

One should also study the methods of constructing curbs. One study examined the following methods to reduce costs (162):

- Delay curb construction until the house construction is complete; and
- Construct curbs with reinforcing to reduce curb breakage.

Sewers

Sewers are constructed under the road pavement and this continues to be a good practice. They should however be constructed in a common trench to reduce construction costs (162).

Many municipalities require 10 inch diameter sewers to handle residential street flows, although 8 inch diameter sewers are more than adequate to handle flows in most residential streets. It is now possible to readily maintain sewers with sizes even less than 8 inch diameter, due to the modern inspection and maintenance equipment.

Reduction in sewer length can be obtained by using curvilinear sewers (no angles). The new total length varies between 5% to 20% less than for straight sewers (197).

Pavements

Narrower pavement width saves land and reduces the capital cost of the road and the cost of the ongoing maintenance. Local roads have usually been around 8.5 m wide (122). This is frequently comprised of 2-3 m wide driving lanes, and a 1-2.5 m wide parking lane (162).

In areas, where off-street parking is available, a local road 8.0 m wide would be sufficient. The reduction of pavement width should be considered in conjunction with the sidewalks for it may not be appropriate to reduce pavement widths if both sidewalks have been removed (161). The Regional Municipality of Ottawa found that a reduction in pavement width on local streets from 5.0 m to 8.0 m would save $30 per meter of road in capital costs (122).

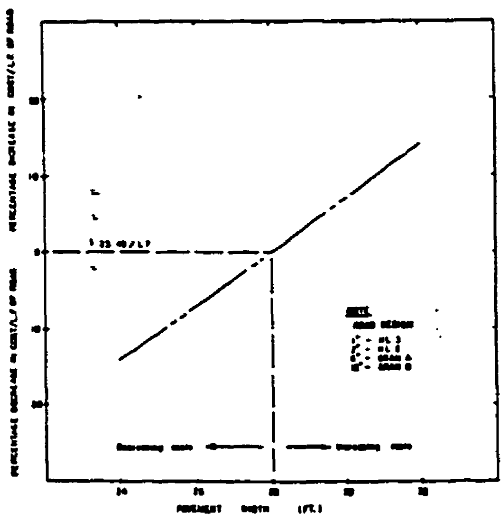


Figure 5.4 Pavement Costs as a Function of Pavement Widths (182)

Smaller pavement width would theoretically reduce the level of service. However, after taking into the account the extent of parking and traffic volume, this may be acceptable in many situations. Pavement widths can be reduced further for one-way streets while still accommodating emergency vehicle access (238). Figure 5.4 shows pavement costs as a function of pavement widths.

Smaller pavement width would also reduce the cost of maintenance and snow removal. In addition, the roads would be safer for the public due to reduced speeds.

Watermains

Consideration should be given to moving the watermains out of the boulevard and under the traveled portion of the road (161). Technological advances have allowed for smaller pipe diameters, greater valve spacing and the confidence to locate the mains under the pavement. Additional savings can be realized by installing valve boxes instead of expensive chambers.

Due to advances in fire fighting, such as longer, and better water hoses, hydrant spacing can be increased. This in turn may eliminate conventional sized mains on some streets, leaving fire-fighting mains on perhaps every second street (122).

Manholes

The currently available sewer cleaning equipment can readily service longer sewer lengths, and therefore the manhole spacing can be increased. It can be seen in Figure 5.5 that the cost of manholes decreases as the spacing is increased. Fewer manholes will result in cost savings along with the cost of maintenance of sewers (281).

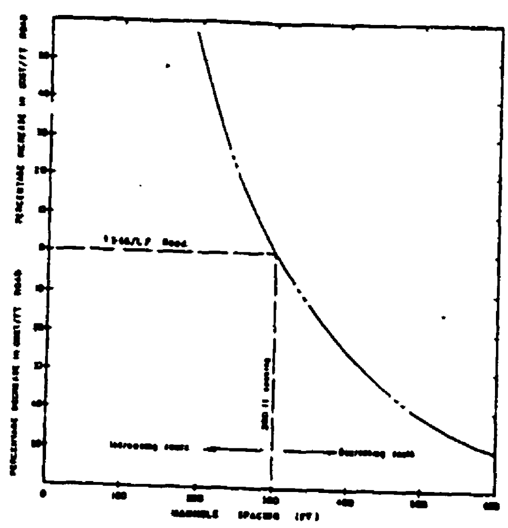


Figure 5.5 Cost of Manholes Per Foot of Road as a function of manhole spacing (182)

Stormwater Drainage

Contemporary stormwater systems designs include efforts to retain water on site, even during heavy storms. The following are some examples of natural drainage systems designed in certain communities (342).

- **Village Homes, Davis, California:** The drainage system consists of small creeks and swales which facilitate the storage of stormwater in a shallow aquifer for use by trees and shrubs. This system eliminated the need for underground storm drains.
- **Glenbrook, Lake Tahoe:** Storm runoff in the streets is deposited through energy dissipaters into open meadows and pastures, where it is absorbed into the groundwater. Runoff from buildings is conveyed directly to the ground using infiltration trenches which are located under the building eaves.
- **Opus 2, Minneapolis:** Roads and parking areas are not curbed to allow the water to flow directly from these areas overland to a series of swales and then into ponds.

Measures to control runoff and reduced filtration include "delaying runoff by holding it on site (in roads, swales, or ponds), expediting infiltration with Dutch drains (perforated pipes laid below the ground surface) and porous pavement materials, and accommodating infiltration by providing temporary or permanent storage basins." (221)

Utilities

To improve aesthetics, utilities are located underground in the road allowance, instead of being located on utility poles. However, this practice may need to be reconsidered because there can be savings of as much as $500 per unit, with the above ground utilities. In addition, the R.O.W. could be dramatically reduced , if no locations were reserved for underground utilities, resulting in further cost savings (161).

Many municipalities provide an assigned location for a utility to be installed in the future as a replacement or reinforcement of an existing system, or a new system. These are labeled alternate utility locations. PVC ducts without manholes are a reasonable alternative to an alternate location and to an expensive system of concrete ducts and manholes (162).

Double Trenching

Usually, each house is served by an individual trench for water, sewer and stormwater lines. This current system con be replaced by a single "y" shape trench serving two units (both single units and townhouses). This single trench would include one water line, one stormwater line and two sanitary sewer lines (Figure 5.6).

The common trench would be aligned along the property line separating the two units. I t would begin at the curb through the boulevard and then separate in a "y" shape at the front property line and reach each unit through its front yard.

It has been estimated by the Task Committee in Ottawa, that the elimination of trenches could save around $200 per unit. In addition, savings in both capital and maintenance costs would be achieved, because there would be minimum interference with the road base (197).

Road Right-of-Way

Existing Standards

A considerable percentage of land within a development is occupied by road allowances. The paved portion is often less than half of the R.O.W (238). The road right-of-way plays a role in determining the face-to-face distance between houses. A reduction in the road right-of-way width is the single most effective engineering contribution that can be made to achieve infrastructure cost efficiency. With more compact housing forms, there will likely be more roads per hectare of developable land and thus reductions in the R.O.W. will have a more significant effect.

Figure 5.7 shows a typical 20 meter local road R.O.W. containing the following components (161):

- 8.5 meter pavement width;
- 5.75 meter boulevards;
- One or two 1.5 meter sidewalk(s);
- Curb and gutter;
- Storm drainage system: sewers, manholes, catchbasins, and foundation drains;
- Sanitary drainage systems: sewers, manholes, and service connections;
- Water distribution system: watermains, valve chambers, hydrants, and service connections;
- Streetlights; and
- Trees.

Proposed Standards

Figure 5.8 illustrates the benefits of reducing the R.O.W. from 20 m to 16 m, and front yard setbacks from 6 m to 3 m. On a typical development having frontages ranging from 6 m to 15 m, there would be a saving of about 10% in the land required without changing the other characteristics of the development (161).

The following are the modifications proposed by the working committee of the Municipality of Ottawa-Carleton, to introduce a 16 m R.O.W. width.

- 8 m pavement;
- Two 4 m boulevards;
- No sidewalks;
- Parking on one side of the road;
- Transformers on easements;
- A joint utility trench;
- Utilities in conduits;
- Front yard servicing;

- Tree on r.o.w. and/or private property; and
- Maximum length of 100 m for cul-de-sac, with 19 m minimum bulb radius.

The Task Committee of Ottawa concluded that adequate clearances between services and utilities could be accommodated by a 16 m R.O.W. width. The pavement width could be reduced because the cars are smaller now. The 8 m pavement allows for parking on the side of the road while leaving enough room on the other side for emergency vehicles. Enough room is provided by the 4 m boulevard on each side for the gas main and a common utility trench. The boulevard also accommodates the 1.5 meter needed for snow storage (296).

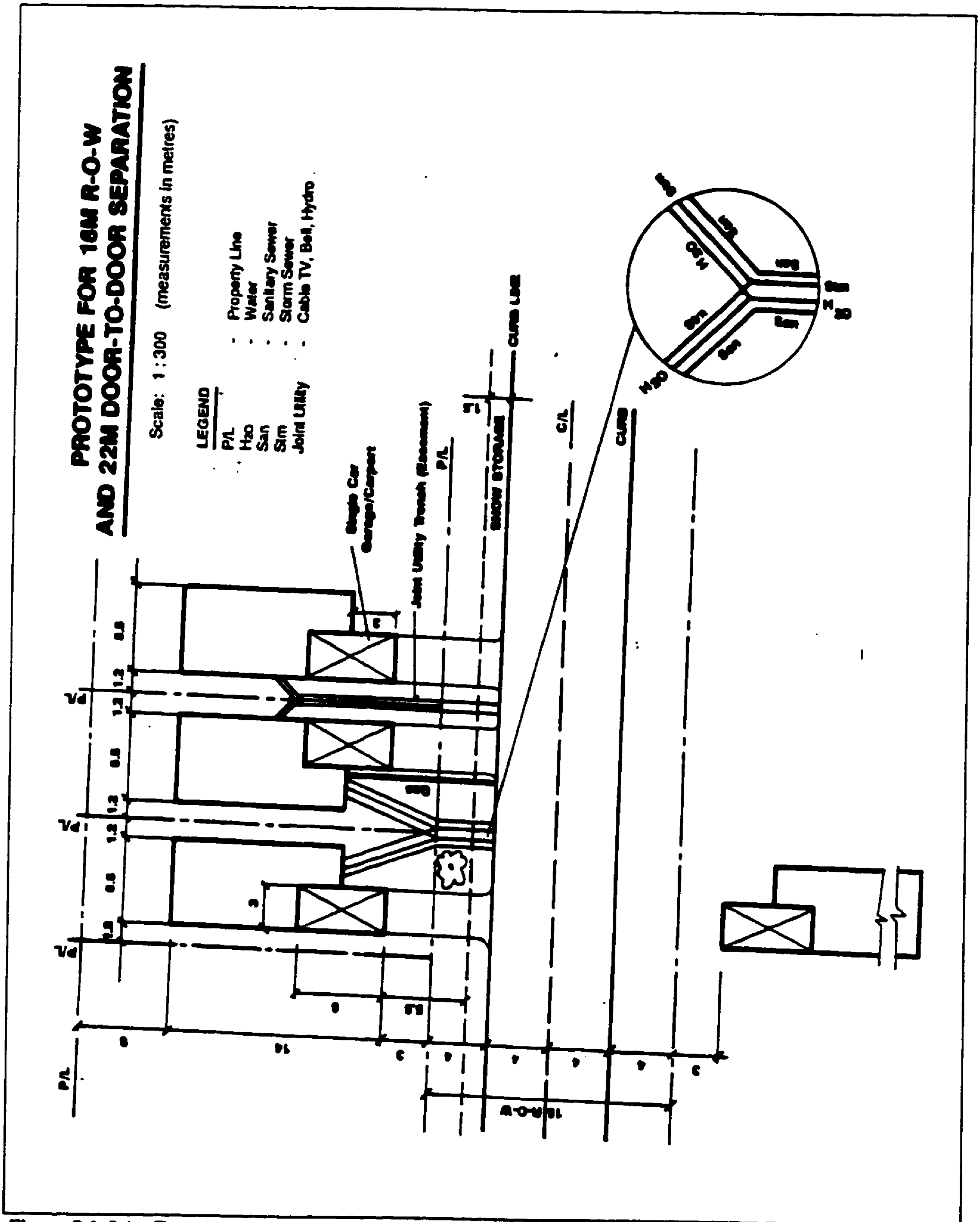


Figure 5.6 Joint Trenching (197)

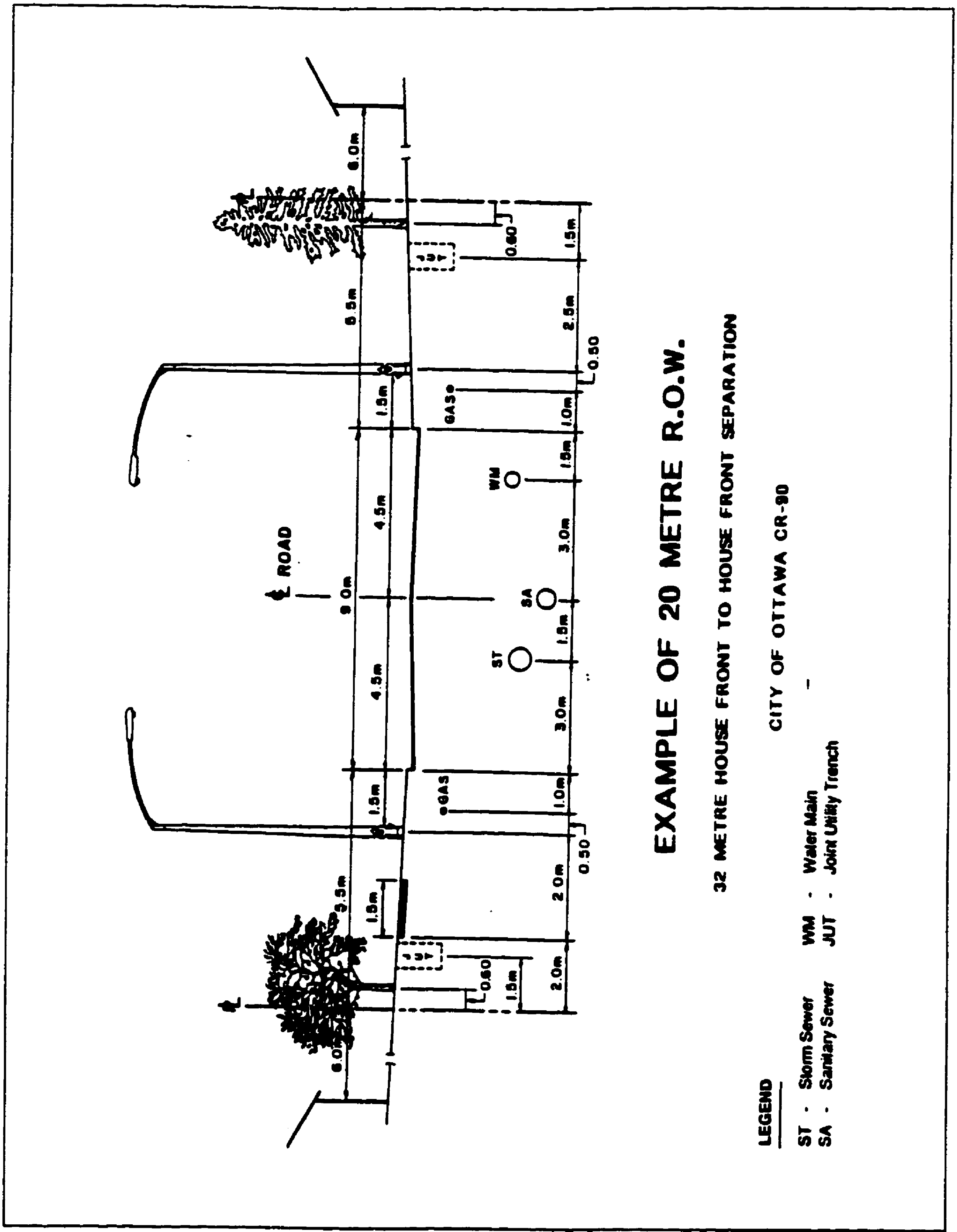
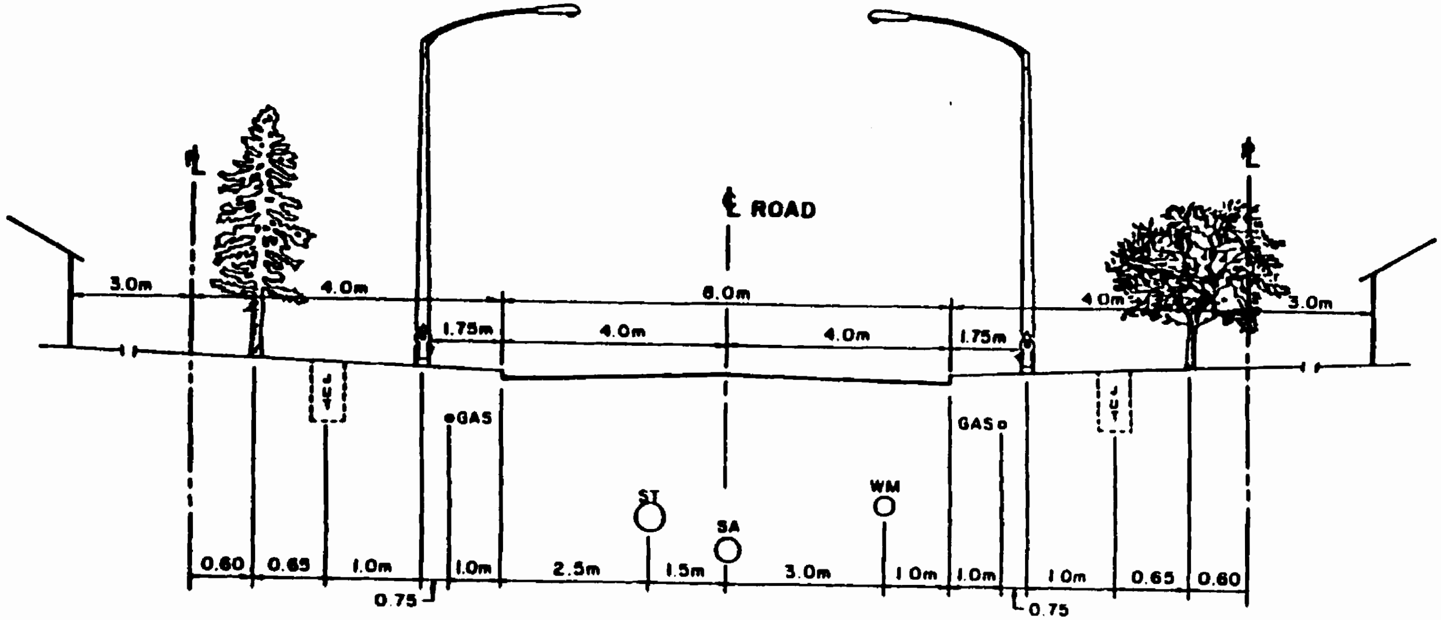


Figure 5.7 Standard Right-of-Way (197)

Figure 5.8 Proposed Right-of-Way (197)



PROPOSED 16 METRE R.O.W.

22 METRE HOUSE FRONT TO HOUSE FRONT SEPARATION

LEGEND

ST - Storm Sewer	WM - Water Main
SA - Sanitary Sewer	JUT - Joint Utility Trench

5.7 URBAN TRANSPORTATION AND SUSTAINABLE DEVELOPMENT

Transportation is an integral part of any modern economy and provides a vital input into manufacturing processes, permits the individuals to enjoy personal mobility for both work and leisure, shapes urban form and is influential in determining the spatial distribution of many economic activities. Virtually all activities have environmental implications and transport is not different in this respect. Previously, environmental concerns in transport were restricted to local factors such as noise, severance and visual intrusion, but recently, the concern has shifted to global warming, acid rain and a range of pollution-induced diseases, giving the regional, national and global implications of environmental degradation more importance.

As incomes grow, so does the volume of traffic. Over the post Second World War period we have seen an unprecedented economic growth in the Western industrialized economies and in parts of Asia. Transportation has also taken on new dimensions as there have been modal shifts. More importantly, there has been a very rapid growth in car ownership and use, which offers greater flexibility in personal travel behavior. However, many view this trend environmentally intrusive and harmful in terms of resource consumption (fuel) from the point of view of the costs of using the vehicle and the resources used in the manufacturing process. Linked with this trend has been the increased urbanization of societies.

Concern over the damaging effects of acid rain on forests and water life mounted in the late 1970s and early 1980s and the importance of NO_X and other gaseous emissions from automobiles was recognized as a major contributing factor. Then the issue of high level ozone depletion and its consequences emerged. Transport does not have just local implications for the environment. It is an important contributor at the local, transboundary and global level. It is also perceived by the population to be a major intruder on the environment since it is highly visible in cities unlike, for instance, agricultural production or sewage disposal facilities, which tend to be located away from populated areas. In addition, transportation interacts with many other areas of activity which are seen as environmentally harmful. For example, the private vehicle is seen as a prime creator of suburbanization and, hence, the reduction of rural and agricultural land (19).

Across the industrialized world, there is a growing awareness that the transportation systems in urban areas are in conflict with the principles of sustainable development. The transportation system in North America, which is primarily based on the private automobile, is not considered sustainable for the following reasons (125):

- Its consumption of non-renewable energy resources;

- Its propensity to encourage a sprawling, low-intensity and inefficient form of urban development, which in turn consumes farmland and natural habitat and which entrenches the dominance of the automobile, as other forms of transportation have great difficulty servicing such dispersed development;
- Its emission of air and water pollutants, which degrade the environment at the local, regional and global scale;
- Its susceptibility to congestion in major urban areas, which exacerbates automotive emissions and energy consumption, inhibits economic competitiveness and generally degrades the quality of urban life; and
- Its direct impact on human life and suffering due to accidents.

Sustainable development is growth based on forms and processes of development that do not undermine the integrity of the environment on which they depend. It is a new path of economic and social progress that meets the needs of the present without compromising the ability of future generations to meet their own needs (157). For urban transportation, this can translate into reducing its contribution to global warming and the consumption of land.

As Commoner points out, the environmental crisis is generated by the clash between the ecosphere and techosphere. Unlike the ecosphere, the techosphere is dominated by linear processes that results in air pollution and the threat of global warming. In other words, in the techosphere (being the transportation system in this case), the goods are converted, linearly into waste, an attack on the cyclical processes that sustain the ecosphere (50).

The establishment of The World Commission on Environment and Development (WCED), commonly known as the Brundtland Commission, by a UN resolution reflected the conviction that it is possible to build a future that is more prosperous, more just and more secure because it rests on policies and practices that are both ecologically and economically sustainable. According to the WCED, the stresses currently being placed on the biosphere are simply unsustainable, in both developed and developing countries, and all nations must integrate environmental considerations into economic decision-making. We need to examine the demand for natural resources (being mostly fuel for automobiles in this case) generated by unsustainable consumption and seek ways of using resources that minimize depletion and reduce pollution. After all, growth should not necessarily mean more waste.

According to Agenda 21, by the year 2000, half the world's population will be living in cities, and Canada is already over 75% urban and states that transportation strategies should reduce the need for motor vehicles. At the macro scale, municipalities need to develop in ways that reduce the need for long-distance commuting and governments should plan urban and regional settlements to reduce the environmental impact of transport and encourage forms of transportation that minimize emissions and harmful effects on the environment (140).

5.7.1 Current Trends and Problems

By the year 2010 there will be over 500 cities with more than a million inhabitants, 26 of them with more than 10 million people (179). Most modern cities have developed to meet the demands of the automobile. Private automobiles have affected the physical layout of cities, the location of housing, commerce and industries, and the patterns of human interaction. Urban planners design around highways, rush-hour traffic patterns, and parking. Private cars can be viewed as both a cause and an effect of our dispersed development patterns since they made development on the rural-urban fringe an affordable alternative to the inner city development, while at the same time, this very development pattern encourages and necessitates massive automobile ownership (60).

Transport planning is required to both ensure that people's needs are met by the least damaging form of transport and also that those needs for transport are reduced. It is necessary to reduce the demand for transport by efficient planning, using both fiscal and land-use measures (73). The relationship between land use and transportation works in two ways: changes in land use can have detrimental effects on existing transportation flows and travel times, but changes in highway capacity can have effects on land use that some policy makers and citizens do not like. The new development encouraged by the new suburban highway changes the character of existing developments, often in ways that existing residents find undesirable (168).

The most obvious unsustainable relationship between land uses and the people they are intended to serve is exemplified by our sprawling residential development patterns and our consequent dependence on private modes of transportation, particularly private automobiles. The private car and single-family detached house have created the single most important challenge to urban sustainability in North America. Based on social, economic and environmental criteria, this challenge consists mostly of reducing dependence on private cars (59).

Zoning is the control tool used by planners to avoid incompatibility between various land uses and to separate those uses which produce negative impacts such as smoke stack industries from housing. Zoning by-law has now developed into a more detailed and intricate set of controls. The by-laws are used to socially segregate different parts of the total residential population by controlling the density and type of dwelling units permitted. At times, these controls are used to protect the financial values of residential properties by excluding those uses which reduce property values (124).

Past practice in land use and urban design has been to divide cities into homogeneous, single use areas of relatively low density. This has resulted in increased auto travel and longer travel distances. For the majority of urban residents, the private automobile is a necessity, rather than a luxury, to move between home, work, shopping, schools, and recreation. Dependence on the automobile contributes to urban sprawl, losses in prime farm land, excess consumption of fossil fuel, air and noise pollution, and traffic congestion (214).

In order to regulate the growing demand for housing in North America, community planners looked at such planning concepts as "The Garden Suburb" and "The Neighborhood Unit" to meet the challenge. Clarence Stein left his mark in Canada with his concept known as the "Radburn Plan". There has hardly been any metropolitan suburb planned in Canada that has not incorporated the following Radburn principles to a degree (60):

- Exclusive residential area of 12-20 hectares with major roads on the perimeter to discourage through traffic;
- Hierarchical roads allowing different traffic needs to proceed only along specialized routes;
- Separation of land uses by the hierarchical road system; and
- Large tracks of open space within residential areas.

Public roads have also been separated from each other. Some examples of the hierarchy produced are (60):

- Controlled access freeways;
- Major limited arterials;
- Arterial roads;
- Major collectors;
- Minor collectors; and
- Neighborhood streets.

Although most high-level, strategic transportation planning and land use planning studies in Canada recognize the strong interaction between land use/urban design and transportation, the underlying theme in many cases until recently has been to assume a continuation of auto dependent development and infrastructure, the delivery of new suburban subdivisions, and the incremental expansion of road infrastructure which often includes little consideration of transit opportunities and requirements (141).

No single force has had a greater impact on the pattern of land development in North America in this century than highways. New population growth is occurring primarily on the outskirts of North American cities. In addition, there is the dispersion of employment opportunities. Industrial operations that were previously in the central parts of the major cities, often adjacent to either rail lines or port facilities, are increasingly moving to new locations on the periphery where good truck access is available, along with larger properties. At the same time, office employment, which was previously concentrated in the central business district is being dispersed to a number of nodes or clumps of development in the suburban areas and to low density, low rise office parks, located at points of high road accessibility.

In general, suburban employment is dispersed along arterial roads and at industrial parks and shopping malls. The explosion of office development in the suburbs has resulted in the total United States office space, outside of central cities, growing from 25% in 1970 to 57% in 1984. With this employment growth has come automobile congestion. Dispersed employment locations are difficult to handle by fixed route transit services or even by van pooling. In 1980, 33% of work trips within the US Metropolitan areas were within the central city, 20% were from suburb to city, 7% from city to suburb, and 40% from suburb to suburb. In addition, the urban system solution of generating dispersed employment works against the use of transit, unless it is located at points of high transit accessibility.

Industrial areas are also isolated from other activities, although they have become cleaner and less of a nuisance than before. As residents are being protected from industries, industries are being protected from other employment activities, since office and retail activities are frequently prohibited from industrial zones. Today, most industrial activities can coexist with residential uses, however, industrial-residential mixing is almost universally prohibited. One result of this segregation of home and work has been an increase in the commuting distances.

Retail commercial activities, which were once part of a neighborhood, have now been separated from residential areas and replaced by a hierarchy of largely single purpose commercial centers. A hierarchy of centers had been developed, from neighborhood to district to regional centers, and large retail shopping plazas with parking have been encouraged. Shopping locations have therefore become farther and farther from homes and customers. In other words, planners are increasingly creating auto-dependent cities (124).

There exists a mismatch within the suburbs, with some communities containing mostly housing and others having far more jobs that there are workers nearby. In addition, there is also a mismatch between the skill levels of new suburban jobs and the income needed to live in the suburbs. This creates a growing labor shortage for suburban employers and a long reverse commute for low-income people in the central city taking suburban jobs (180).

Significant steps need to be taken to make urban travel more sustainable. In comparison to older, geographically smaller, more densely populated European countries, North America has a particularly challenging task in achieving transportation sustainability. Canada, for instance is a vast country with a small population with its low density cities often separated by great distances. Therefore, there is a high level of energy consumption by the transportation sector and a high level of auto-dependence and auto use within urban areas. In comparison to US cities, where central areas have been depopulated and original transit systems dismantled, there are good prospects for improvement in Canadian cities, where the core areas have largely retained their vitality and a full range of functions such as the transit systems (125).

Table 5.5 illustrates the issues surrounding the development of more sustainable communities and transportation.

Table 5.5: Global and Community Planning Issues (59)

GLOBAL ISSUES	COMMUNITY PLANNING ISSUES
Energy: • climate change • air pollution • diminishing resources	• energy efficient urban planning • inter and intra-urban transportation
Land: • land degradation • land use change • climate change • competing uses • diminishing resources	• urban sprawl • urban intensification

Most residents in North America place a high value on living in a semi-rural environment and driving their cars to work, shopping, recreation, and every aspect of their daily lives. The resulting urban sprawl and automobile dependency is expensive in terms of infrastructure requirements, environmental damage, and equitable service to all sectors of the population. These costs are becoming increasingly unbearable both economically and politically. Some people can afford this way of life by spending more to support their expensive habits, but many cannot. Many people are becoming weary of long commutes and worried about the disappearing countryside. (190).

5.7.2 Strategies for Sustainable Development in Urban Transportation

Sustainable development provides a difficult challenge for us all, but it also provides a unique opportunity to make changes which will create a healthier environment.

No single policy instrument will solve the problem due to important and complex role of transportation in the North American economy and the magnitude of changes that would be required to decrease or eliminate its contribution to global warming. Since passenger travel in cities represents the largest share of North American transport energy use and greenhouse emissions, the largest reductions in emissions will come from measures directed at reducing the energy consumed in urban passenger travel.

The level of transportation sustainability is directly related to the level of private automobile use in North America, and any sustainable strategy must involve a reduction in automobile use. This strategy would not just reduce care usage, but reduce car dependency for many types of trips. The ability to provide good alternatives to the automobile such as frequent, reliable and efficient public transportation (transit) is dependent upon the population densities and urban form (125).

Changing patterns of settlement to reduce the need for travel can lead to long-run reductions in emissions. This can be accomplished through higher densities, and mixing uses so that residences, jobs and services are roughly balanced at a local level. When more destinations are close to home, more trips can be made through other means such as bicycles and by foot, and when densities are higher, public transit can serve more trips effectively (180).

Possible initiatives for urban structure and urban design policies are:

- High density;
- Mixed land use;
- Sub-centers;
- Internalizing environmental costs
- Joint transportation/land use planning; and
- Regional planning institutions

More intensive land use planning and more emphasis on sub-centers can lead to (125):

- More economic use of land;
- More economic use of all physical and social infrastructure;
- Less impact on rural fringe;
- Reduced emissions;
- Less road accidents;

- More human city centers;
- More equitable transport systems; and
- More urban cities.

Intensification and Infill

To reduce the usage of the private automobile, intensification of land uses will have to be implemented and planners will have to move away from the present development patterns. Municipalities will need to remove those regulations and requirements that would prevent intensification (124). There is a large public opposition that usually accompanies conversion, infill, and redevelopment projects. This opposition, known as NIMBY or "Not In My Backyard" syndrome, focuses on fears about over crowding, loss of community character and declining property values (60). They should also permit intensification of development and the introduction of mixed uses along the lines of traditional commercial shopping areas. Finally, municipalities will have to permit residential, retailing, and other employment activities in older industrial areas which have been vacated.

Infilling applies to the construction of new facilities, usually residential developments, on vacant land in an existing developed urban area. Intensification relates to the redevelopment of land for similar use but at a higher site density. The redevelopment of obsolete industrial areas for other purposes such as housing is beginning to receive attention.

A better mixture of uses results in greater amounts of two-way commuting. The balance produced by two-way commuting also makes better use of the existing transit services. A mixture of residential and employment uses also provides the ability for individuals to live and work in the same location (124).

Growth Management

Growth management is a technique to try to limit or stop population growth, an attempt to balance the demand for new services with the supply of existing services and a way of limiting urban sprawl. By limiting the sprawl of new housing into surrounding agricultural and other non-urban lands, growth management attempts to save farmland for farm purposes and to encourage intensification within the already built up area in order to utilize the existing facilities more fully. However, one of the negative affects of limiting growth is leapfrogging. New residents would jump over the area of controls and locate in adjacent municipalities beyond the control limits. This would in turn produce an inefficient regional settlement pattern and transportation costs and individual commuting times would be higher (124).

One way to increase the market for higher-intensity development is to restrict the supply of developable land, by limiting the spatial extent of urban development. An urban growth boundary (UGB) now surrounds each large city in Oregon. These boundaries are intended to preserve land outside the urban fringe for agricultural and forestry uses, and increase the efficiency of urban development by increasing development densities and using existing infrastructure capacity. As growth expands, the demand for developable land rises. But since this boundary restricts developable land, the price of land increase, which in turn promotes intense (higher density) development. Therefore, the UGB potentially prevents urban sprawl at the urban fringe and also promotes development at higher density throughout the urban area (168).

Density

Low-density development increases transportation energy demand, air pollution, vehicle miles traveled (VMT), and natural resource consumption. Modest changes in density are possible through changed zoning and infilling. However, urban residents resist increasing densities due to the resulting traffic congestion, although with fixed travel needs, congestion is higher in lower-density areas. In order to reduce congestion, measures such as zoning and building fees, will have little effect on congestion unless coordinated over entire metropolitan areas, and may even increase congestion if they reduce opportunities for people to live near work. Settlement controls needed today for congestion and emissions are of the opposite kind to those now proposed, and the kind that reduce travel demand are those that mix residences and workplaces, mixes income groups, at higher densities (180).

A 1989 study verified empirically the relationship between density, transit, and automobile use, using 32 cities from around the world. It concluded that the amount of energy devoted to transport depends on "activity intensity"- a measure of city land use based on the concentration of residents and jobs per hectare in a metropolitan area. Gasoline consumption and automobile use appear to be inversely related to the overall urban densities and to the strength of the inner city (measured in persons and jobs per hectare). The data indicates that gasoline consumption in US cities varies by about 40 per cent between newer, low-density, relatively weak-centered cities such as Houston, and older, high-density, relatively strong-centered cities such as New York. Theoretically, cities like Houston and Phoenix could save fuel by 20 to 30 per cent, if they were to become more like Boston or Washington in urban structure.

In older suburbs, policies are needed to increase densities, create mixed-use nodes and corridors, and improve pedestrian access and the pedestrian environment (141). With higher densities, transit systems become more economically feasible. A denser, more compact urban form which can be served by transit is necessary to reduce auto usage and to handle the overall commuting demands (8). If density increases, transport needs decrease and the bleak prospect for public transit may be improved (206).

Regional Planning Boards

What is required presently to effect the necessary changes in the areas of land development standards and transportation planning, is the incorporation of sustainable urban development principles, into the planning process (60). In addition, land use and transportation planning need to be fully integrated. Sustainable development requires a coordinated approach to planning and policy making. Local authorities have a key role to play in making sustainable development happen, since they oversee the planning of housing and industrial development, set local environmental policies and help to implement the national environmental policies (157).

Metropolitan regions are needed to look out for the metropolitan good and to consider the future development of the region as a whole and incorporating the strategies for sustainable development. Such organizations should have the mission and budget to formulate workable regional plans, and powers to influence funding allocations and implementing regulations throughout the region, and overriding decisions made by local councils on critical issues. In general, they should be responsible for determining the conformance of local plans with regional plans and for reporting inconsistencies to the local governments.

But before such an organization can make any decisions for metropolitan development, a new vision of entire regions must be formed. For instance, it should be made clear at the outset that all future development will incorporate the principles of sustainable development. A constituency of concerned citizens would be fundamental to work toward the vision of the future metropolis. It is important to define closely the many interests affected by the current environmental and transportation problems, including business and consumer groups. Finally, regional actions to determine and implement related land use and transportation futures will require the support and the undertaking of major initiatives by federal and state/provincial governments (190).

Therefore, with a regional government in place, a long term urban development plan (20 to 30 years), at the macro level, needs to be created to provide a context for future growth. The plan should incorporate economic, social, and environmental aspirations, and integrate land use and transportation. The plan may include the following elements (214):

- Development of major multi-use town centers in suburban areas, integrated with regional transit;
- High density, mixed use development along major transit corridors;
- Transit funding and operating priority where densities and demand levels make this possible; and
- A grid pattern of highways and arterials to accommodate truck traffic and passenger demand that cannot be handled by walking, cycling or transit.

Integrated Land Use and Transportation Planning

It is evident that in order to make urban transportation more sustainable, both land use and transportation systems planning needs to integrated. It is important to note that subregional (municipal) planning is not likely to be successful in the absence of regional planning, and neither is regional planning in the absence of an empowered regional government. Therefore, regional governments with powers, is a necessary condition for successful regional planning. Although plans for different regions differ in many ways, they should all have some common features to integrate land use and transportation planning such as (168):

- Long range vision and comprehensive consideration;
- Broad brush approach (a consequence of their comprehensive plans, and the limits of budget, time, and methods);
- Pro-involvement (a consequence of the need for regional solutions and public involvement); and
- Pro-visioning (a consequence of all the above).

5.7.3 Current Initiatives

Regional planning institutions are taking shape in some parts of North America and in some cases, strategies for sustainable development are being incorporated. Although some municipalities or regional municipalities are on the right track, we still have a long way to go in most parts of the country.

In order to address the problems of urban sprawl and encourage coordinated planning and delivery of urban development and infrastructure by the five regional governments, the Province of Ontario has created the Office of the Greater Toronto Area (OGTA). Its common goal is the nodal urban structure concept which emphasizes compact mixed-use redevelopment/development based on greatly expanded transit services (125).

Recent planning suggestions have begun to encourage the development of more intensive nodes and corridors. Work on the GTA Concept Study and for the Metropolitan Toronto Official Plan have encouraged the development of nodes of activities located at positions with high transit accessibility and linked together by corridors functioning as transit lengths, where a medium density development must be encouraged (124).

The Metropolitan Toronto official plan encouraged the growth of suburban town centers and the new Official Plan will set out planning strategies for the "reurbanization" of Metro Toronto by encouraging intensification and the redevelopment of selected arterial roads into main streets.

The Province of Ontario has other excellent policy initiatives such as the "Transit-Supportive Land-Use Planning Guidelines", as well as "Growth and Settlement Policy Guidelines" which require that peripheral development should be restricted until internal sites are fully developed (125).

The City of Vancouver recently adopted a "Clouds of Change" report which includes strategies to reduce the need for transportation in the city and region through land-use planning. Its principles have been embodied in Transport 2021, Vancouver's current plan of developing a Long Range Transportation Plan for the region. It incorporated the following recommendations of the Federation of Canadian Municipalities relating to the macro scale (125):

- Encourage greater density through multiple unit residential developments;
- Integrate work, residence and shopping in mixed use development;
- Zone higher density development along established routes;
- Decentralize commercial and community services to reduce travel distances, creating self-contained communities with better balance between employment and population;
- Place controls on outlying shopping centers, strip development and urban sprawl; and
- Encourage the infilling (development and redevelopment) of existing vacant and under utilized land in built-up areas.

A report by the Ontario Round Table on the Environment and Economy and the National Round Table on the Environment and Economy, called A Strategy of Sustainable Transportation in Ontario, suggests the following strategies (179):

- Education and awareness;
- Focus on more compact mixed-use communities;
- A shift from automobiles to transit; and

- Cleaner, more fuel-efficient cars.

By 1996, every local authority should have developed a local agenda 21. Local officials are required to consult citizens, business and industrial organizations, to gather information and build a consensus on sustainable development strategies. The consultation process will increase people's awareness of sustainable development issues and the consensus would help shape local programs, policies, laws and regulations to achieve Agenda 21 objectives (140).

Twenty one municipalities have been selected from around the world as model communities that can show local leadership in achieving sustainable development goals of Agenda 21. Based on its VISION 2020, the regional municipality of Hamilton-Wentworth is one those communities, and the only one in Canada. It is a vision for the region, 25 years from 1993, developed through community consultation and based on sustainable principles. A new Official Plan was prepared for the region, which incorporates the strategies and actions in Vision 2020.

The process to create a sustainable region involved a comprehensive public participation program resulting in a vision for the future, which has been adopted by the Regional Council. The vision is a presentation of citizen's ideas and views of the kind of community Hamilton-Wentworth can be by the year 2020. It challenges government, citizens, business and community groups to think about how their actions can move the society towards a more sustainable future. The vision is supported by strategic directions and the Regional Official Plan is a key instrument in the implementation of these directions, and consequently the physical creation of a sustainable region.

The Regional Municipality of Hamilton-Wentworth was created in 1974, comprising six area municipalities. The division of responsibilities between the Region and the Area municipalities has been set out in the various acts and municipal policies, and is currently under review. The Plan is intended to direct and guide regional, area municipal, public and private decisions and actions, in a consistent and logical manner, to manage change and growth in the area. Since the plan is a policy document, it is expected that detailed land use policies and designations will be enunciated through the municipal official plans. In addition, the Regional Official Plan will respect those planning interests that are the sole responsibility of the area municipalities.

Once the Official Plan has been approved by the Minister of Municipal Affairs, the Planning Act and the Regional Municipality of Hamilton-Wentworth Act require that no public work be undertaken and no municipal bylaw passed which does not conform with the Regional Official Plan. In addition, all Area Municipal Official Plans and Zoning By-laws must be revised, where necessary, to conform to the Regional Official Plan.

The Plan intends to prevent scattered rural development and establish a firm urban boundary. The Plan recognizes the fact that a compact higher density urban form, with mixed use development in identified regional and municipal centers and along corridors, best meets the environmental, social, and economic principles of sustainable development. It prefers mixed forms of development within an urban area to widespread, low density residential development and scattered rural development.

An integrated transportation system (combining transit, vehicles, bicycles, air, and water transport and pedestrian movements) will be developed which stresses easy pedestrian, transit and vehicular access to all basic needs and supports a sustainable development pattern. Since there is a direct link between land use planning (density, mix and proximity of uses) and transportation, emphasis will be placed on accessibility and reducing reliance on the automobile by promoting alternative modes of transportation, such as transit and cycling to all urbanized areas of the region (110).

Another good example of a successful initiative undertaken at a metropolitan level is the city of Curtiba, Brazil, where progressive city administrators build their policy based on a preference for public transportation over the private automobile, working with the environment instead of against it, appropriate high technology solutions, and innovation with citizen participation.

Curtiba does not have a gridlocked center fed by overcrowded highways, like other major cities. Its authorities emphasized growth along prescribed structural axes, allowing the city to spread out while developing mass transit that kept shops, workplaces and homes readily accessible to one another. Land use legislation has encouraged high-density occupation, together with services and commerce, in the areas adjacent to each of the five main axes, along which the city has grown. Since three quarters of all commuters take the bus, per capita fuel consumption is 25 per cent lower than in comparable Brazilian cities, and the city also has one of the lowest rate of ambient air pollution in the country.

The city managers of Curtiba have learnt that good systems, coordination of policies, and incentives are as important as good plans. One of the most important lessons to be learnt from Curtiba's experience, is that priority should be given to public transport rather than to private cars and to pedestrians rather than automobiles. In addition, solutions to urban problems are not specific and isolated but rather interconnected. Bicycle paths and pedestrian areas should be an integrated part of the road network and public transportation system. While intensive road building programs elsewhere have led paradoxically to even more congestion, Curtiba's policies have generated less use of cars and has reduced pollution (149).

In general, these proposed strategies are the best solutions for making the transportation systems more sustainable and less environmentally hazardous. While other alternatives such as making cars more efficient, introducing electric cars, and higher fuel taxes, are also important and necessary, they do not fall into the domain of urban and transportation planners. Planners need to incorporate the principles put forward in this paper if they wish to solve current transportation problems. Not all solutions put forward are perfect, such as the urban growth boundary, are suitable for all regions, but they are a good start and planners will have to incorporate those strategies which best suit their metropolitan area.

It is also important to realize that the unsustainability of the urban transportation system is a global problem, since global warming affects everyone, however, the actions needed to make the urban transportation system sustainable, are local in nature. Therefore, we must act locally, but think globally. We must also take measures that produce long term effects, and not just for the short term benefits as in the past, since short term solutions do very little to solve the problem in hand for the future, and the environment should always be dealt with serious consideration for the long term effects.

5.8 SUMMARY

Civil engineers must stop inflicting any further damage to the state of the planet and try to solve what has already been damaged. They should examine new and innovative ways of designing, constructing and managing our housing and infrastructure. This can be achieved by incorporating sustainability into the current engineering practices. They must possess the knowledge of how to eradicate the problems which have resulted from the procedures followed in the past. They have a very important role in guiding the society along a sustainable development path. Therefore their future role should be the prevention of any damage to our environment and natural resources, and this can be achieved by incorporating sustainability into the current engineering and construction practices.

In North America, municipalities are still utilizing relatively conventional or traditional planning and development standards. In the last several years, demand for standards that permit more compact, affordable, and innovative community design, has increased. In order to achieve cost efficiency and effectiveness, alternative development planning approaches have to be examined that demand innovation from architects, engineers and builders, and require compromise and flexibility in the municipal regulations. Innovations in municipal standards can reduce the cost of housing and at the same time, reduce the financial burdens of the municipalities.

Man has been passive to the end of nature (the destruction of the physical and natural environment). We feel that changes in the natural world happen very slowly. Ornstein and Ehrlich find that humans are unable to perceive changes (and therefore threats) quickly because our sensory systems have been developed to cope with only a small set of changes in the environment. We tend to block out a lot of changes in our environment since responding to them will be too bewildering. Our biological rate of evolution has kept pace with our cultural evolution and seems to constrain our ability to react quickly enough to the changes created by our social and technological evolution. The authors of New Mind New World characterize our predicament as being similar to a frog boiling slowly in water. It is the gradual change in temperature that ultimately proves to be fatal. Like the frog, we are in a crisis but our senses are not detecting the danger (72).

It is important to accept the reality that behavior pattern of people will not change significantly in the future. In addition, it is going to be a great challenge for the government to divert people from their automobiles. Those concerned about urban transportation and its effect on the environment can no longer wait for people to start behaving as they should: living in compact, high-density residential development patterns, traveling short distances to work along well-defined corridors to destinations in orderly, compact business districts, using public transit in large numbers, and being very socially conscious in their selection and very limited personal use of the automobile.

Therefore we need to take immediate actions and work on modifying our current engineering practices to incorporate the concepts of sustainable development into future practices. Engineers, planners and architects should work together, and not against each other since sustainable development can only be achieved through the cooperation of different disciplines that play a significant role in infrastructure. Sustainable development should not be an option, but a necessity, and long term plans for metropolitan regions should be developed in the immediate future. Academia will also have an important role to play here, by teaching the concepts of sustainable development to all future planners and engineers.

6.0 MANAGEMENT OF INFRASTRUCTURE AND SUSTAINABLE DEVELOPMENT

6.1 INTRODUCTION

The task of managing Canada's infrastructure is shared among the different levels of government; Local (Municipal/Regional), Provincial and Federal, and increasingly with the private sector. Although many governments at all levels have attempted to address the present infrastructure crisis, there are serious weaknesses in the infrastructure management systems. As different governments have their own set of unique approaches to manage their infrastructure, the result is that infrastructure throughout Canada is not in uniform condition with some municipalities faring better than others.

It was observed by the FCM's survey in 1984 that many municipalities were unable to provide data relating to their current needs, past expenditures and activities of their public works departments. Poorly maintained infrastructure is also the result of poor management practices (101):

- Public works expenditures are made without adequate management information about status, condition and the capacity of existing infrastructure.
- Many municipalities continue to reduce the funds available for maintenance.
- At times, public works projects are not viable in the first place since the practice of underestimating needs, or poor management are not uncommon.

Sustainable development can help achieve a balance between economic development and the environment. We cannot slow down or stop economic development, which includes the development of new infrastructure facilities, to preserve a healthy environment, but we can develop it in a sustainable manner so that our future generations will also have their share of the natural resources and the environment. Planning for sustainable development implies keeping our future needs in a correct perspective, and not just having a short-term outlook; we must try to reduce our waste, and to keep a balance between economic development and the hazards to the environment (66).

Recognizing our role in the degradation of our environment, we must find and develop ways of managing these facilities in a manner which would achieve sustainable development over a long period of time. We also need to find better ways of managing these facilities as the economic, planning and environmental pressures grow, and as the current system of co-operative, inter-jurisdictional basis of management has been inefficient.

Developing an effective management approach is a long-term way to handle a problem as large as our current infrastructure crisis. Engineering skills alone will not be adequate to resolve this crisis. We need to examine the skills needed to manage infrastructure and how they should be applied. Engineering skills need to be complemented by solid management skills. There is more to infrastructure management than planning, building, and operating infrastructure facilities. This chapter briefly examines at the skills needed to manage infrastructure in both the public and private sectors.

6.2 GENERAL MANAGMENT

Management is the process of attaining organizational goals by working with and through people and other organizational resources. It has the following characteristics (6):

- It is a process or series of continuing and related activities;
- Involves and concentrates on reaching organizational goals; and
- Reaches its goals with the help of people and other organizational resources by assigning activities to the organization members.

Managers guide organizations toward goal accomplishment. They have the responsibility for combining and using organizational resources to ensure that organizations reach their goals and achieve their purpose.

The four basic management functions are (6):

- **Planning:** It involves choosing tasks that must be performed to attain organizational goals, outlining how the tasks must be performed and indicating when they must be performed.
- **Organizing:** It involves the assigning of tasks developed during planning to various individuals or groups within the organization.
- **Influencing:** It involves guiding the activities of organization members in appropriate directions.
- **Controlling:** This is ongoing process for which managers:
    - Gather information measuring recent performance within the organization;
    - Compare present performance to pre-established performance standards; and
    - Determine if the organization should be modified to meet pre-established goals.

6.2.1 Leadership

Leadership is the process of directing the behavior of others toward the accomplishment of objectives. It causes individuals to act in a certain way and to follow a certain course. In other words, leadership gets things accomplished through people.

Management and leadership qualities of infrastructure managers are important for infrastructure to function efficiently and to be maintained effectively and economically. The managers need to be aware that politics and ethics play an important role in the management of infrastructure and that simply having a good business degree is not enough. Running a public organization is more complex than running a private organization where the goal is to make a profit and you have complete freedom in the way you run the business. However, in public organizations politicians are involved, and therefore a lot of patience and understanding of the political system is required. Some of the successful traits of leaders are (6):

- Intelligence, including judgment and verbal ability;
- Past achievement in scholarship and athletics;
- Emotional maturity and stability;
- Dependability, persistence, and a drive for continuing achievement;
- The skill to participate socially and to adapt to the various groups; and
- A desire for status and socio-economic position.

" Management is a generic term meaning to handle all decision making, planning, organizing, and administrative aspects of an enterprise. Leadership means providing inspiration and extraordinary inputs to the enterprise" (106).

Personal skills needed for a manager are (106):

- Time management;
- Interpersonal relations; and
- Good work habits.

Knowledge-based skills needed are:

- Financial management;
- Public relations techniques;
- Technical skills (computers).

Infrastructure managers need to be leaders, supervisors and technical managers. The three aspects of planning that are of great importance to them are:

- Organizational management;
- Building physical systems (project management); and
- Operational management.

The process of decision making is an important part of managing infrastructure and would ideally utilize techniques such as decision theory, statistics, and operations research. (80) However this process is distinctly absent from infrastructure management since most of the decisions are made at the political level.

Effective supervisory techniques, involving control of the facilities after the planning and organization processes have been completed, are also required for managing infrastructure effectively.

6.2.2 Organization

Productivity and performance of an organization greatly depend on management, leadership and organization (106). Organizing is a process of establishing orderly uses for all resources in the organization. It enables people to work in an effective and efficient manner. It is extremely important to the management systems because it is the primary mechanism with which managers activate plans. The five steps of the organizing process are (6):

- Reflecting on plans and objectives;
- Establishing major tasks;
- Dividing major tasks into subtasks;
- Allocating resources and directives for subtasks; and
- Evaluating the results of implemented organizing strategy.

Unfortunately, reorganization of a public organization requires political and bureaucratic effort, unlike private organizations. An organization can be split into the following units (106):

- Department;
- Division;
- Section;
- Branch;
- Unit, etc.

Each of these units requires a manager or a director, and a job description needs to be given to each of the individual positions in these units. Then, every level of the organization needs a plan that also comes in handy at the accountability stage where evaluation is based on how well the plans were carried out. This plan should include:

- Mission statements;
- Goals;
- Objectives; and
- Work plans.

Organizations should have two elements such as line and staff. The line part relates to the direct work of the mission and the staff provides the support for the line operation, financial management, administrative support, logistics, and planning. An organization can be either a line-and-staff or matrix organizations.

Each manager or worker should report, as far as possible, to only one supervisor. The path of communications, control, command, and intelligence should be straight with as few levels of supervision or staff as possible.

Some of the techniques necessary to make an organization effective are:

- Job classifications;
- Position descriptions;
- Work plans;
- Management by objectives; and
- Salary schedules.

After the structure of the organization is set, the individual jobs and assignments must be set. If the jobs are successfully carried out, this will lead to a successful accomplishment of the overall work of the organization and to the achievement of the organizational mission. It is again the performance of the key employees in these jobs that determines success, because the effectiveness of an organization depends on the quality of the individuals which can change with time.

The design and evaluation of the work in individual jobs must be planned and performed according to a fixed cycle, like annually. After the objectives are set, tasks can be assigned carefully and effectively.

Evaluation of the results is an essential part of an organization, and it is followed by rewards, increases in pay, promotion, and recognition. Then it is time to set new goals (106).

6.2.3 Communication

Communication is a process of sharing information with other individuals. Information in this context is any thought or idea that managers desire to share with other individuals (6). Communication within an organization plays a very important role in ensuring its success or failure. If communications are healthy, workers and managers are more likely to be productive.

One model explains why communications are often not successful in organizations. It explains the flow of communications in terms of the social climate and the need-value motivational frameworks of the communicators. The model explains some of the difficulties found in organizations. The social climate is explained by an *open system* or a *closed system* within which communication takes place. The characteristics of the open system are mutual trust, open relationships, concern for well-being, and emotional security of all workers and managers. The closed system features lack of trust, distant relationships, little concern for well-being, and low emotional security (106).

A vital tool for communication for mangers and other staff is the preparation of reports. It facilitates the planning process, because after being documented, the report can be distributed to the various departments involved for evaluation and further study. The preparation of reports in the management process enables the managers to (106):

- Report on the status of the project;
- Present an inventory of needs and resources;
- Report on the possibilities for expansion or development; and
- Make specific recommendations for project development and financing.

Communication also involves being up to date with the current issues and technologies in infrastructure and sustainable development. Engineers can disseminate information in the following ways (210):

- Municipal associations;
- Professional journals;
- Trade magazines;
- Newsletters;
- Technical reports;
- Conferences, seminars, workshops etc.;
- Training programs;
- Municipal reference libraries;
- Information clearinghouses;
- Computerized networks and databases, including the Internet.

Other sources of information include (96):

- Consultants;

- Other municipalities;
- Federal and State/Provincial governments;
- Guidelines and standards; and
- Universities and research centers.

6.3 PLANNING INFRASTRUCTURE

Planning is a simple concept used to find or develop tools to achieve organizational goals, to make decisions about the actions needed and to solve problems (106). It is a process that determines exactly what the organization should do to accomplish its goals (6). The advantages of planning are:

- It helps managers to be future oriented because they are forced to look beyond their normal everyday problems to project what may confront them in the future;
- It helps mangers to coordinate their decisions; and
- It emphasizes organizational goals which is the starting point of planning.

It is basically the first step in the process of infrastructure management and plays a very important role in managing organizations of all types. Unfortunately, very little planning is undertaken in public organizations. The different types of plans that cross the path of infrastructure managers are (106):

- Policy plans by senior levels of governments (federal and provincial);
- Master plans including comprehensive plans for regional development based on needs and development of each type of infrastructure;
- Capital development plans;
- Financing plans;
- Organizational development plans; and
- Plans for the improvement of operations.

As planner of new infrastructure facilities, the engineer must examine concurrent planning approaches. This means that planning, design and operation of infrastructure facilities is done on the basis of an entire system, and not just keeping an individual facility in mind. Examples of this are (66):

- **Sewers:** Storm and sanitary sewers, which extend across several municipal boundaries, need to accommodate different patterns and rates of population growth, water use and runoff conditions. Changes in any of these factors affect the treatment plants and the water course that would eventually receive the effluent.
- **Water:** Increase in water use overloads septic systems which in turn can contaminate groundwater aquifers over a wide area.

- **Stormwater:** Untreated storm runoff can pollute downstream water courses.

There are several other examples illustrating the effects that infrastructure facilities have on their surrounding environment and therefore the planning, management and administration of these facilities should be undertaken in an integrated fashion.

6.3.1 Integrated Planning

Currently, infrastructure facilities are operated and managed locally by the respective municipalities. This jurisdictional splitting has produced several problems since environmental problems have no boundaries. Decisions taken at the local level can have a major bearing on the regional system. These impacts can be both negative and positive, but to ensure efficient operation of the infrastructure, we need to practice a unified and integrated approach to planning, designing, financing, operation and maintenance. Some of the problems that have resulted from this current method of management in the Ottawa-Carleton sewage collection system are (66):

- Lack of integrated planning involving the trunk system which is regional and the local sewers which are municipal;
- The measures adopted to tackle the flooding problem were local and in effect simply transferred the problem to a downstream location;
- The financing and rate settings vary between regions and result in non-optimal capital priorities;
- The officials are unable to optimize the operation of the entire wastewater collection and treatment system; and
- There are several different training and human resource development programs.

Traditionally, solutions for environmental issues are sought at the municipal and regional levels. However, most of the solutions brought forward are either ineffective or too expensive to launch and operate. Perhaps, it is time to formulate alternative solutions to the current issues, starting ideally with the consumer, or the general public itself. They can have the largest potential for providing the whole society with a sustainable future and environment. We need to focus on changing the homeowner's habits regarding solid waste disposal, water use and wastewater generation.

Local governments have assumed many responsibilities some of which in the past were dealt by individuals, such as boulevard grass cutting and sidewalk snow clearing. The government assumption of these responsibilities has resulted in (66):

- Changed environmental impact;

- Dependence on these services; and
- Increased cost to the taxpayer.

Infrastructure systems should not be planned solely by technical professionals such as engineers, but also by other professionals such as sociologists, planners, politicians and economists, mainly because a single technical solution or project does not always necessarily provide the correct or complete solution to a problem. The best overall solution that would benefit people from all walks of life, results from integrated approaches and measures. The environmental assessment procedure has opened doors to other professionals and the engineer, who used to be the sole provider of the technical solutions for infrastructure, is now becoming one of the contributing team members. This type of team effort is necessary for achieving a wide variety of solutions to any problem, and is also fast becoming the way most engineering problems are handled presently. However, most engineers do not have the experience or training to work in teams that consist of members from such diverse fields as sociology and economics. Infrastructure managers require a high degree of strategic planning and communication skills to deal with the concept of making public works decisions based upon uncertain and indistinct criteria and based on a variety of technical, political, social, economic, jurisdictional, and environmental issues.

6.3.2 Technology Management

Technology management is a new approach to solve environmental problems by changing lifestyles and habits, rather than by technical solutions. This approach cannot only be more efficient, but also requires minimal expenditure. This can be achieved by focusing on the following areas (66):

- **Conservation** applies to land use, natural vegetation, habitat, minerals, aggregates, water and energy.
- **Prevention** is the reduction or elimination of waste generation and discharge emissions at source.
- **Optimization** maximizes the efficiency, productivity and use of existing infrastructure systems.

Services required in both the private and public sectors to implement technology management are (66):

- Policy analysis;
- Strategic planning;
- Project planning;
- Feasibility studies;

- Environmental assessments and impact studies;
- Approvals;
- Compliance;
- Audits;
- Training and education;
- Public participation;
- Information management;
- Specialized project management and construction management; and
- Commissioning and decommissioning of facilities.

6.3.3 Growth Management

The demand for infrastructure is driven by land use, growth and development (106). Infrastructure managers should be aware of land-use management since infrastructure problems occur both in rapidly growing areas and in old declining areas. A significant portion of infrastructure management revolves around land use decisions which are made by planners.

Growth management, a process that accommodates new developments, has arisen because it is almost impossible to stick to any static plan for land use. It is not surprising that all development plans undergo changes due to changes in local social and economic demands and needs. The different methods of growth management are (106):

- Public acquisition;
- Public improvements (infrastructure);
- Environmental controls;
- Development rights transfer;
- Zoning techniques;
- Conventional subdivision regulations;
- Regulations for permanent population controls;
- Zoning and subdivision controls relating to off-site facilities;
- Tax and fee systems;
- Annexation;
- Capital programming;
- Geographic restraints; and

- Numerical restraints and quota system, and others.

6.3.4 The Planning Process

The five steps of the planning process are (106):

- **Identifying the Problem:** This step determines the cause of the problem by filtering all conflicting reports several of which are biased and management consultants are often given this important assignment requiring very basic understanding.
- **Goal-Setting:** Occasionally, the goals are determined by a political process and at times it is not possible to set goals without an election. The different candidates running usually raise issues which they feel may be important or attract attention. Issues considered are usually brought forward by the candidates with the most votes.
- **Formulating Alternative Solutions:** This step requires considerable creativity on the part of the managers. The different types of alternatives are:
    - Technical alternatives;
    - Financial alternatives;
    - Organizational alternatives; and
    - Management alternatives.
- **Evaluation of Alternatives:** This scientific process requires the help of computers for efficiency. It involves systems analysis, economic, impact analysis, and political awareness.
- **Selection of Alternatives:** In this process, the alternatives are ranked and presented to the decision maker. This is a discrete step for the decision maker and often in complex situations, planning decisions may not be made for long times.

Some of the most common forms of planning arising in infrastructure are (106):

- **Policy Planning:** This is the development of the overall policies that will govern the entire programs and approaches, including the need to subsidize the infrastructure for improved economic development in a given region.

- **Program Planning:** This is done for each service category and includes both operating and capital aspects of these services.
- **Master Planning:** It helps plan the overall immediate goals of a facility and assists with the establishment of its direction.
- **Implementation Planning:** This includes action planning to solve problems and to develop preliminary design, which represent a detailed process between pure planning and construction.

6.4 OPERATION STRATEGIES

Operations management is concerned with implementing what was planned in the planning phase of management and is therefore the last phase of problem solving and planning. It is aimed at providing maximum productivity within the organizations. An operations manager is faced with the following questions (106):

- Is the system organized properly?
- Is the staff organized properly?
- Is the work planned thoroughly at all levels?
- Are the operations adequately controlled?

To ensure that the operations is adequately controlled, the manager needs to check whether the product or service is being delivered adequately and whether the condition of the facility is acceptable.

Control of Operations

Control of operations involves the actual control of the system through a functioning organization equipped with the right control devices. Communication includes all the data flow, telecommunication, etc. and intelligence is the collection of data required for management and decision making.

Productivity

The basic objective of production management is to provide the required levels of service at the least cost to the public. This introduces **productivity management** as a tool for measuring how well the organization is performing. It is the measurement of the output of the organization as a function of the input. Irrespective of the type of organization, there is a product that can be identified and measured.

6.4.1 Quality Control (QC)

Control is making something happen the way it was planned to happen. Mangers need to control and check to make sure that organizational activities and processes are proceeding as planned. The three main steps of the controlling process are (6):

- Measuring performance;
- Comparing measured performance to standards; and
- Taking corrective actions.

Quality control ensures that the quality of the product (for instance the quality of water from a water treatment facility) is within defined acceptable limits.

The principles of Total Quality Management (TQM) are beginning to receive considerable attention due to the search for solutions to the current environmental problems and to achieve new sustainable forms of development. These sustainable forms of development can be implemented during the planning, design, construction and operation of a facility to reduce the short and long-term impacts on the environment. This concept of project sustainability provides (115):

- Enhanced energy efficiency;
- Increased recycling of resources; and
- Reduction of waste generated by construction projects.

If TQM is applied properly, it can assist the design and construction by improving the following (115):

- Process efficiency;
- Competitiveness;
- Return on investment;
- Employee motivation;
- Company image;
- Quality of products and services; and

- Commitment to meet customer needs.

6.4.2 Sustainable Quality Management (SQM)

The construction industry needs to be more environmentally conscious and it must change its traditional ways of managing construction projects. The new methodology that is beginning to be adopted by some environmentally conscious construction companies is called **sustainable construction.** It establishes the link between the environment and the development objectives(115). An examination of the objectives of sustainable development proposed by WCED (World Commission on Environment and Development) in 1987, makes it quite apparent that there is great potential in achieving sustainability in the construction industry as it is responsible for providing the infrastructure to transport and handle food and other products, and to provide water and sanitation services. It can achieve sustainability by (115):

- Developing the necessary infrastructure to support social and economic growth;
- By improving the quality of their products and services;
- Conserving and optimizing the use of non-renewable resources; and
- By promoting the efficient use of energy.

The SQM process improves the quality of social and private growth by continually improving the quality of process productivity, products and services. It is the "application of continuous improvement to the corporate process for achieving sustainable development." The phases of the SQM implementation process are (115):

- **Awareness and Commitment:**
  - Recognizes the need for realigning the current business thinking and practices to embrace the concept of sustainable development; and
  - Corporate statements and policies are formulated for achieving quality and project sustainability.
- **Planning:**
  - The company resources and the strategy for implementing SQM are identified and developed;
  - Support personnel for the green/quality teams are identified and selected; and
  - Corporate green/quality teams are formed to support the program structure.
  - The teams are responsible for:

- Defining the specific sustainable quality measurement;
- Development and implementation of the plan for educating and training the middle management and the employees; and
- Development and implementation of the schedule and the budget for the sustainable quality program.

- **Full Assessment:**
  - Internal or corporate assessment: the corporate or project green/quality teams identify, understand and clearly document the existing corporate practices and procedures to gain the maximum benefit from the SQM implementation process;
  - External or customer assessment: customer needs and requirements are defined and met; and
  - Environmental assessment: the environmental impacts by all products, materials and processes are assessed.
- **Implementation:**
  - The preparation and assessments of the previous phases are translated into action;
  - The pilot projects for implementing the SQM process are selected; and
  - Life cycle analysis is undertaken.
- **Monitoring:**
  - The project green/quality teams maintain and evaluate the measurable goals established in the previous phases;
  - Corrective actions are taken immediately; and
  - Results of the monitoring phase need to be documented and spread throughout the organizational levels.
- **Improvement:**
  - The project lessons learnt are reflected in the next planning stage by setting new goals and objectives and modifying the overall organizational procedures.

The SQM can help achieve sustainability since (115):

- The project team can address the full implications of new materials in terms of manufacturing procedures, installation, handling, use, reuse, recycling and disposal;
- Designers and engineers can use this information for project or product assessment;
- The implementation of SQM to reduce, reuse, and recycle building materials can significantly reduce the environmental impact of construction projects and preserve natural resources; and
- It provides services that have minimal or no adverse environmental impact;
- It encourages the use of products which are safe in their handling and intended use;
- Uses products that are energy efficient;
- Reduces the amount of waste generated;
- Optimizes the use of natural non-renewable resources;
- Uses products that can be reused and recycled;
- Develops and designs new facilities within the sustainable urban development practices; etc.

6.5 PROJECT ENGINEERING

The construction process involves:

- Bidding;
- Review;
- Award;
- Organization;
- Construction;
- Inspection; and
- Acceptance.

Regarding infrastructure project management, the principal roles of the engineer are (106):

- Maintaining the quality of construction;
- Keeping records such as as-built drawings, the official standards and the surveys;
- Determining the final quality of work; and
- Inspection to ensure that the work is completed according to the plans and specifications.

The design and construction of both new and renovated projects require management skills for efficiency and success since these two processes are very complex with diverse elements. Under current situations the task of managing such projects has become ever more complex due to the demands of sustainability. Sustainable projects in the future require new approaches to management and education, communication and technology to support them.

There is a need for extensive front-end work in the design and construction sector. There should be a full understanding of what is involved and a more precise definition of environmental design problems needs to be formulated. For this, more explicit goals need to be established that would be both achievable and appropriate for the budget, schedule, owner's requirements and sustainability. Case-based reasoning should be used where one of the goals is to avoid disadvantages of inappropriate standards and regulations since new decisions and choices are based on the past projects and experiences. This is an efficient technique for decision making as examples are used to avoid past failures while achieving past successes. However, for this technique to succeed, proper documentation of past cases is essential.

Cased-based reasoning may prove to be a difficult task since each construction project is different from the previous one, which makes it difficult to establish standards for facility programming, investment strategies, budgeting, scheduling and ensuring environmental sustainability. An alternative approach would be the use of expert systems. These are tools that capture human expertise and disseminate it in situations where knowledge is scarce (remote areas, distributed decision making cases or automated systems).

In most projects, decision makers only take the short-term goals and objectives into consideration. However, they should balance long and short term gains and also look into local versus global objectives. Businesses and large facility clients in the public sector are generally motivated by the business end of their operations, however, they should also take into consideration the impact that environmental design, engineering, construction, and management can have on the organization and project success.

Environmental impact affects both the natural environment and the organization. The organization feels the pinch through employees, consumers and voters that may impact the bottom line of the organization. Organizations should note that the public would be more sympathetic to organizations and products that are sustainable and environmentally conscious.

The common types of plans found in the project planning phase are (106):

- **Reconnaissance Phase:** Identifies those possible projects that meet the goals established in the overall planning and development process. It leads to recommendations for further studies.

- **Feasibility Phase:** Establishes definite feasibility, including financial, technological, environmental, and political.
- **Definite Project Phase:** Results in plans, specifications, and operating agreements.

6.5.1 Value Engineering

Value Engineering is a useful tool used for improving productivity, reducing costs and increasing profits. In the construction industry, it " is a combination of heuristic and scientific techniques used to analyze either a building system, building material, or construction method." (97) It is an investigative process during which all life-cycle costs relating to design, construction, operation, maintenance, and replacement, are considered. Life cycle costing is an approach to buying that places emphasis on quality by going for the lowest ownership cost, rather than the lowest bid price. After the investigative process, items that contribute to the escalation of the project costs without affecting its quality, safety, reliability, performance and maintainability are analyzed. A value engineering study is conducted using a plan that is carried out in five sequential phases (97):

- **Information phase** during which one becomes familiar with the design, searches for areas with great potential for savings and improves performance and performs a functional analysis.
- **Speculation phase** during which alternative ways to achieve the same function of building components are searched.
- **Analytical phase** during which the best alternatives are picked from the ideas generated in the previous phase.
- **Proposal phase** during which recommendations for cost reduction alternatives are formulated.
- **Report phase** involves the formulation of the results of the study with appropriate recommendations.

In construction, value engineering can be applied during any phase, but optimum results are normally achieved if it were to be carried out during the early design phase. This is due to the fact that during this stage, the decision of the engineers and architects have the greatest impact on the total cost. Finally, it is important to note that value engineering differs from other cost-reduction techniques because it saves costs by questioning methods, materials and processes used.

6.5.2 Project Management System

A project management system (PMS) is a networking system that utilizes an integrated approach to successfully control and direct a project. Economic analysis, value engineering, and life-cycle costing, are tools that help in planning. Project administration is broken down into (106):

- **Preconstruction phase** which involved checking the funds for availability, obtaining land acquisition contracts, requisitioning the project, assembling contract documents, evaluating bids, obtaining contractor's signatures on contract documents, and issuing the notice to proceed.
- **Construction phase** which involves reviewing contract documents, holding the pre-construction conference, assisting in obtaining permits, receiving and reviewing work schedules, financial information, processing requests for payment, managing change orders, and handling all reporting.

6.5.3 Contractual Relationships

The construction industry loses a lot of valuable time in the avoidance or resolution of claims. Disputes arise due to conflict of interest between the owner of the project and the contractor. The owner wants to receive the most value for his construction dollar, while on the other hand, the contractor wants to spend the least amount of money while meeting his contractual obligations.

The construction industry now relies on the design engineer or the architect to clarify the requirements of the contract and to decide on the corresponding responsibilities of the parties, however, this does not work out due to the owner's desire to save time and money during the design phase. As a result, there is not enough time for the architects and the engineers to complete their designs fully prior to the calling of the bids. In addition, the owner may require that construction begin prior to the completion of the construction documents so that the building can be occupied as soon as possible. Misunderstandings and disputes are, therefore, most likely to arise. Thus, the seeds of dispute are usually planted long before the first contractor arrives on site, or before the team-building takes place. For this reason, it is imperative that a solution be brought forward that would avoid any disputes in the design stage when the contract documents are being prepared.

Two of the most often suggested solutions are (36):

- Alternate Dispute Resolution (ADR); and
- Partnering.

However, neither of these two solutions is cost-effective or dispute-free, since with the exception of arbritation, they lack the means of enforcement and their success depends on the good will of the individuals involved.

Risk allocation and dispute avoidance, though essential to safeguard the financial well-being of the industry, are not sufficient for assuring the achievement of the goals of sustainable development. Since both the developers and the contractors are guided by their respective financial interests, the goals of sustainable development do not form an important part of their planning process.

Currently, it is the owner of the project that sets the goals and the budget. Therefore, the engineers and the architects should educate the owner about the costs and the methods of achieving sustainability in construction, preceded by a detailed knowledge of sustainable development in engineering and construction. In addition, both the architects and the engineers must be freed, wherever possible, of some of their management and judicial responsibilities, imposed by their contract, so that they can devote most, if not all of their time to the design of the project.

The task of maintaining our standard of living while trying to prevent the accelerated depletion of our natural resources is a huge and difficult responsibility, that can only be entrusted on a professional such as the architect or the engineer, who are the only ones to undertake the responsibility of satisfying the prerequisites of sustainable development in engineering and construction. This enormous task should not be left for the developers and their contractors. They simply do not possess the background knowledge required to assume this enormous responsibility. However, the architects and the engineers should not be held liable for achieving the desired goals of sustainability, in other words, they should not be held responsible for the consequent damages. This is due to the fact that innovation in engineering design will not occur when there is the fear of liability and the notion of defensive design has to be practiced. Engineers and architects will be very reluctant to try new innovative ideas since they may be held liable for the consequences. Only when this enormous burden is lifted off their shoulders, would they do all they can for achieving the goals of sustainability.

Since the current forms of contracts do not meet the perceived requirements for sustainable engineering and construction, a new form of contract needs to be devised which would allocate the risk involved between all parties concerned: the architect and engineer, the owner and the contractor. The construction industry can adopt the New Engineering Contract (NEC) published by the Institution of Civil Engineers (of the UK). This contract establishes the position of Project Manager, who is independent of the designers and has broader powers. Although the owner is burdened with more risks than before, he also has much more direct control of the project through the project manager. Most importantly, the designers and architects are isolated from the task of managing the project and can therefore concentrate on achieving the desired goals of sustainable development (36).

6.5.4 Improving the Management of Design and Construction Projects

Different parties are often involved in the conception, financing, planning, design, construction, operation and maintenance of the project. Each of these parties have their own financial and other goals which may differ considerably from the others, and at the same time each of the participants are seeking to reduce their individual risks and to avoid responsibility. This will ultimately lead to adversarial relationships between the parties involved. It is, therefore, imperative that all the stakeholders define a common set of goals to be pursued jointly during the development of the project. Successful project goals may include (36):

- Lowest cost;
- Shortest time to complete the project;
- Highest quality;
- Economic viability;
- Functionality;
- Responsiveness to user needs; and
- Economic and environmental sustainability.

Currently there are several kinds of design and construction delivery systems due to different:

- Types and sizes of firms;
- Types and sizes of projects;
- Contractual arrangements;
- Private and public owners; and
- Systems of rules and regulations governing design and construction practices in different locations.

The most common type of construction method is the Design-Bid-Build method. However, new forms of organization and management have emerged to find organizational answers to the conflicts which may arise among the parties and to find more effective and efficient delivery systems. Some of these systems are:

- **Project Management:** Places a project manager on the side of the owner to foster better decision making.

- **Construction Management:** Efficiently manages the design and construction process.
- **Design/Build:** One organization or company performs both the design and construction duties.
- **Design/Build Plus:** Other players such as a financier, lessor, land owner, operator and maintainer, are added to the Design/Build team.
- **Partnering:** Establishes a charter among the parties to act as a team and share the risk. A platform is provided for all parties to work towards common goals. It is a system of procedures which define the relationship, the responsibilities of the parties, procedures for joint evaluation of progress, and dispute resolution.

The success of all forms of design/construction delivery systems relies heavily on good communication between all participants. One of the major barriers to communication is long distances, and different languages and cultures. In addition, personal contact is replaced by electronic interaction. However, with growing advances in electronic communication, distances should no longer remain a barrier, but there is still so much room for improvement in methods of interpersonal communication. Good communication depends upon (36):

- Understanding the interpersonal relationships of those employing the technologies;
- Understanding the driving force which allows for open interaction;
- Educating design and construction personnel in interpersonal relationships as well as technology;
- Open communication based on trust;
- Changing the legal system to allow easier resolution of conflict;
- Development of integrated interdisciplinary software and collaboration among participants;
- Improved models and methodologies for sharing data;
- Improved global information exchange on methods to achieve sustainable engineering and construction; and
- Learning to listen more and talk less.

6.6 FINANCIAL MANAGEMENT

6.6.1 Controlling the Municipal Budget

The beginning of financial planning is the budget process which details the services to be offered by the program or project, the revenues and costs, and the final determination of the extent of success of the venture.

Budgets are useful in all phases of management, including planning, organizing and controlling. The budget document itself is supposed to function as a policy document, an operations guide, a financial plan, and a communications medium. It should be planned well in advance of the budget year.

The budget process is a general cycle of planning, negotiating and implementing a budget. The preparation of a budget will determine the resources that are available. Both the operating and the capital budgets should be planned and programmed on multi-year cycles. A brief review of the various budget systems follow.

<u>Capital Budgets</u>

This is the procedure for budgeting for capital items having lifetimes longer than one year for instance. It needs to be related to capital programming in the sense that the budget should be programmed in advance by preparing plans, estimates, and studies to justify the budget requests. A 5-year capital program would show capital expenditures for 5 years in the future, beginning with the following budget year. The capital budget should be linked with a comprehensive infrastructure planning and needs assessment process.

Departmental financing is directly tied to capital budgeting and decision making. It involves determining how much money is needed and when, and to find the best financial deal.

<u>Operating Budget</u>

The operating budget is linked with plans for services, organizational development, and the development of programs on an on-going basis, normally on an annual basis. It is the primary vehicle for management use of budgeting where all of the details of expenses and revenues are projected, approved and reported. The objectives of an annual operating budget are (106):

- Providing an interdepartmental informational vehicle to aid in planning;

- Requiring the executive branch to produce an estimate of expenditures so that the adequacy of revenues can be checked;
- Providing a means to the different levels of management to evaluate the internal competition for resources;
- Using in-work planning and evaluation;
- Communicating with the policy overview body the operating objectives of the coming year and making revisions based on input from that group;
- Providing the information to base the annual appropriation ordinance;
- Providing the base by which annual plans can be adjusted to conform to appropriations; and
- Providing a basis for financial audit of the enterprise.

The operating budget must be viewed in a definite cycle. In the year that the budget is spent, the funds available are those that were approved during the previous fiscal year. In the budget planning year, the organization might be required to submit some estimates of funds needed for instance a multi-year period. In the budget preparation year, there would be detailed planning, leading up to the approval by the mayor, council, and/or finance committee for the following year's budget. There may therefore be three budget years in a manager's life: one for planning, one for approval, and the third for operating.

Operating funds should come from current revenues, with minimum reliance on subsidies whenever they can be avoided. Revenue sources normally used for infrastructure management are user charges, property, and other taxes. Because operating budgets have to be renewed every year, they should be financed from recurring revenues (106).

Planning-Programming Budgeting System (PPBS)

This system is intended to provide for the scheduling and furnishing of resources within the department on the basis of project needs and program needs regardless of any jurisdictional considerations. It also includes the full spectrum of technological and fiscal planning, programming, and budgeting of resources of all kinds, as well as a thorough evaluation of the objectives, programs, and projects. The evaluations are normally followed by revisions in the budget.

Program Performance Budgeting

City services and departments are broken down into their functional units or programs, and the services which the city provides are examined closely. A list of performance indicators is submitted along with each department's budget request. These are designed to be a statistical measure of how well a program is achieving its goals and objectives. This type of budgeting makes it easier to examine programs and services to determine how they can best meet the community goals and priorities.

Zero-Based Budgeting (ZBB)

The zero-based budgeting system was developed to eliminate the funding of activities without systematic annual regard for priorities or alternative means of accomplishing objectives. ZBB is a comprehensive budgeting process that systematically considers the priorities and alternatives for current and proposed activities in relation to the organizational objectives. Annual justification of programs and activities is required to have managers rethink priorities within the context of accepted objectives. ZBB requires managers to reevaluate all activities at the start of the budgeting process to make decisions about which activities should be continued, eliminated, or funded at a lower level.

ZBB is especially applicable in the support and service areas where non-monetary measures of performance are available. However, it does not provide measures of efficiency, and it is difficult to implement because of the significant amount of effort necessary to investigate the causes of prior costs and justify the purposes of the budgeted costs.

The three steps of the ZBB process are (20):

- Converting the organization activities into decision packages. A decision package contains information about the activity, objectives and benefits, consequences of not funding, and the necessary costs and staffing requirements.
- Ranking each decision package.
- Allocating resources according to priorities.

ZBB demands considerable time and effort to be effectively employed. It also requires a wholehearted commitment by the organization personnel to make it work. One of the major benefits of ZBB is that the managers focus on identifying non-value added activities and working to reduce items that cause money to be spent unnecessarily, or ineffectively. Managers may consider zero-basing certain segments of the organization on a rotating basis over a period of years as an alternative to applying the approach to the entire organization annually.

Planning and Programming in the Budget Process

The planning phase of budgeting brings other program and facilities planning into the budget process. For infrastructure facilities, it means to connect the budgeting process with capital improvement planning. To connect budgeting with the other processes of planning, the manager must ensure that the managers and the planners at the different levels are aware of the need for interaction with the financial staff, and vice versa.

Programming is part of budgeting and can be implemented in different ways. The main difference between the two is the level of commitment. The programming of the budget can be considered to be just planning ahead for the different aspects of budgeting. The program is basically a statement of plans to ask for the budget authority. The most visible budget program is the capital improvements program.

When budgeted and initiated, the program becomes binding and the facilities that are initiated will have to be finished. Programs for new operating budget requests are less binding since they can be altered without reversing capital commitments.

6.6.2 Accounting for Infrastructure

Financial management provides the funds necessary to plan, build, operate, and maintain facilities, and the information necessary to control the facilities and the management organization.

Control is accomplished through accounting and auditing, with its reports, checks and balances. Auditing is the process of examining accounts, or making an outside check on the validity of the financial management and the health of the organization. It also provides suggestions on how things can be done better. Cost control is a matter of ensuring that the full value is received for every dollar spent.

Financial control also involves built-in checks of the organization for control of purchasing, the fixed-assets records, the inventory, and the control of hiring through staff activities.

The basic elements of financial accounting are (106):

- **Trial accounting instruments** are used to show the effects of management actions on the future projections of the financial health of the organization.
- **Income statement** provides an estimate of the differences between revenues and expenditures over a period of time. It uses a financial control device with the main interest in cash receipts and cash disbursements.
- **Balance sheet** provides the final changes in assets and liabilities over the accounting period.
- **Cash budget** is the most important analysis instrument in public enterprises that must be managed to recover costs and be self sufficient financially.
- **Financial report** is the key report which contains the overall results of the past year's activities, including operational and fiscal performances.

- **Revenue analysis** leads to a determination of the revenue sources available and feasible from an economic and political basis.
- **Cost analysis** considers the construction costs, the operating and maintenance costs, and the cost of regulatory programs and the continuation of planning
- **Institutional analysis** is concerned with the ability of existing or planned institutions to manage the program.
- **Ability-to-pay analysis** involves a determination of the capability of the community and its citizens to bear the cost of the service.
- **Secondary impacts analysis** examines the economic, social, and environmental effects of infrastructure programs.
- **Sensitivity analysis** examines the changes in the outcomes of the analysis that result from changes in the assumptions (e.g. water metering).

6.6.3 Elements Contributing to the Success and Failure of Organizations

There are three critical elements which contribute to success that can be examined for their relationship to planning (106):

- Firstly, planning is extensively linked to budgeting through the formal planning procedure which incorporates planning and programming into budgeting.
- Secondly, management should be concerned about the long-term effects and provide overall mechanisms to ensure their careful consideration.
- Thirdly, up to-date information on physical capital should be incorporated into the decision-making process with the appropriate long-term considerations.

There are several factors that make an organization successful. The following are elements found in successful organizations:

- Recognizes the effect of deferred maintenance and attempts to minimize it.
- Protects capital investment funds from being used in operations.
- Considers related operations and maintenance costs when making capital budgeting decisions.
- Monitors capital investments and the condition of physical capital.
- Uses funding mechanisms to protect priorities.
- Uses incentives to meet work and financial targets.

- Considers alternative methods of meeting the objectives of capital investment projects.

Elements found in unsuccessful organizations are (106):

- Planning is not linked to budgeting when planning takes place.
- Little attention to long-term effects.
- Does not consistently feed information on the condition of the physical capital into the decision making process.
- Defers structural maintenance and focuses on cosmetic repairs.
- Permits funding mechanisms to drive priorities.
- Has limited, if any controls, and misses many financial work targets.
- Allows special interest groups to get out of control.

6.7 INFRASTRUCTURE MAINTENANCE

Analysis in deciding to replace or rehabilitate should include projections of demand, explorations of alternative ways to meet demands, evaluation of the rates of deterioration and obsolescence, cost-benefit, and impact studies and recommendations.

The most important factor in the decision is the cost factor, or what termed the economic evaluation. In other words, is it more economical to rehabilitate or replace? At times the structure may have deteriorated to such a level that replacing it may be the only solution. However, there will be cases where rehabilitation will be the best solution economically. But the best alternative cannot always be determined easily, and detailed studies will have to be undertaken. There may be cases where rehabilitation may seem to be the right solution in the short run, however, in the long run it may be more costly than just replacing the infrastructure in the first place.

Economic evaluations provide a basis for defining the best alternative. However, their usefulness lies in their mathematical accuracy, precision in details, and user objectivity. The work program for each option should be projected over an initial time period. Every planned task is associated with cost. After the calculations have been done, the results are interpreted, and the best solution chosen.

The first step in deciding to replace or rehabilitate old infrastructure is the needs assessment process. It depends on the inventory, the condition assessment, and an identification of the desired levels of improvement and maintenance.

6.7.1 Maintenance Decisions

Maintenance of infrastructure consumes a large share of public works funds. It depends on the availability of funds, and not on needs. Deteriorating infrastructure is not repaired as often as is necessary, because it is not politically compelling and is not popular among the general public either. It is the development of new facilities that attracts both the political and public attention.

Maintenance must be supplied at different levels and has implications for both the operating and the capital budgets. Preventive maintenance is intended to head off problems. Corrective maintenance involves repair, replacement, and rehabilitation of facilities. A maintenance management system (MMS) is a program for ensuring that the overall maintenance program is managed adequately. It involves planning, organizing, controlling, and an effective decision support system which would provide data for the condition assessment, preventive maintenance, and corrective and major maintenance works (106).

Some of the options for improving maintenance are (171):

- Improved accountability to improve performance measurement.
- Set aside reserve funds for maintenance and sinking funds for replacement where bonds fund the public works.
- Equipment design and facility construction should take maintenance into account and maintenance managers should be consulted in the specifications for any equipment.

The ongoing maintenance of the infrastructure facilities is other area in infrastructure management that is vital for a sustainable future. During economic times, it has always proven more convenient to dismantle existing facilities and rebuild them, rather than maintaining them on a regular basis, or rehabilitating them. In the current situation of shrinking economic financial constraints, the municipal budgets have shrunk and it is always easier to cut back on maintenance and operation expenditures. Besides such neglect is not as apparent as building new projects which are aimed at attracting more public attention for political reasons. This lack of investment in keeping our infrastructure in good condition, has led to a deplorable state of our roads, sewers, bridges, just to name a few. As mentioned earlier, the cost of upgrading infrastructure facilities to an acceptable level are staggering.

This must change if we want to achieve a sustainable future. Environmental demands which are now high and our current economic condition, which will probably not revert back to what it used to be during good economic times, are now forcing us to use our current facilities in an efficient manner. We seriously need to optimize our infrastructure by enhancing our operation and maintenance practices. The importance of operation and maintenance are (66):

- Efficient operation;
- Optimal environmental performance;
- Maximum capital investment; and
- Continuos benefits.

The policy options available to the municipal agencies must focus on integrated planning and operation strategies to achieve higher benefits and efficiency. The policy directions are (66):

- **Flexibility and Adaptability:**
  - Budgeting and priority setting must be adapted to the needs of the entire system; and
  - Develop flexible planning systems that reflect short-term budget constraints through incremental facilities expansion and innovative service concepts.
- **Meeting Peak Demands:**
  - Municipal infrastructure should accommodate average conditions rather than peak demands.
- **Standards and Criteria:**
  - Standards and design criteria should be more innovative and cost-effective.
- **Levels of Operation and Maintenance:**
  - Service levels must take costs and benefits, optimal use of existing infrastructure and long-term operation, into account.

The development and implementation of preventive maintenance programs is necessary for the better management of infrastructure facilities. It supports maintenance versus replacement and rehabilitation decisions, plans and schedules the maintenance and capital improvement activities. This requires up to-date information and familiarity with the technologies available for the task. In addition, the critical areas of maintenance, monitoring, and rehabilitation of the infrastructure need to addressed to keep the infrastructure in an acceptable condition.

Organizational procedures and the general philosophy of maintenance management have to be instituted in the civil engineering profession as a means to enhance the effectiveness of infrastructure management. Infrastructure facilities should not be neglected until their condition constitutes a crisis, nor should they be replaced simply because they are old. Proper maintenance practices along with good data management can help with decisions related to replacement, rehabilitation, or repair.

Maser classifies maintenance and capital improvement decisions into the following three levels (139):

- **Strategic Planning Level:** Decisions are made at the overall organizational level. Budget allocations and priorities are defined. Involves long-term projections, project selection and evaluation, resource programming in manpower and equipment, and financial planning.
- **Operational/Control Level:** Decisions are made regarding the various inspection methodologies, capital improvement options, and their relative cost/benefit ratios, packaging of maintenance contracts, repair/replace/rehabilitate decisions, and in-house versus outside contracted implementation. General guidelines and approximate maintenance needs and policies are also defined.
- **Tactical Level:** This is the component level of decision making. Involves timing and frequency of inspections, required level of detail, and implementation control of maintenance plans related to infrastructure system components such as pipe segments, pavement sections, etc.

6.7.2 Framework for Investment Decisions

In order to maintain existing infrastructure, public works officials need to address the following two questions (174):

- What level of investment is required?
- What specific projects should be selected?

Generally, these decisions are reached either systematically or in an ad hoc manner. Lists of projects deemed necessary by the officials are reviewed and those that fall within the available budget are selected. This practice is not acceptable if we are to maintain our existing infrastructure in an efficient manner. O'Day and Neumann propose the following needs assessment framework which lists critical steps needed to be undertaken to develop investment needs estimates (174):

- **Develop a Facility Inventory:** An accurate inventory of all infrastructure facilities including technical and maintenance information, needs to be established and updated regularly.

- **Establish Performance Criteria and Conduct a Conditions Assessment:** A set of facility performance criteria needs to be established to evaluate the conditions of the infrastructure facilities, which should be reviewed periodically and not be too restrictive. Current national standards may not be appropriate in certain cases since they may not reflect the local conditions and problems. Systematic surveys of all facilities should be conducted regularly to assemble consistent information on all facilities so that the current and the likely future condition can be determined.

- **Identify Deficiencies:** Elements of the facility that do not meet the criteria need to be identified by comparing the facility condition survey results with the facility performance criteria. Once the deficiencies are identified, the follow-up analysis need to be performed to define alternative projects to correct the deficiencies.

- **Develop Funding Scenarios and Program Priorities:** Facility needs should be determined with reference to potential overall budget levels since definitions of needs and priorities can change dramatically due to specific resource constraints. Funding constraints or scenarios should show what can be done for the various levels of budget above the existing levels. Some guidelines on the priorities that should be addressed at any level should also be established.

- **Develop and Evaluate Alternative Projects:** Alternative improvement levels or projects should be developed for facilities identified as deficient. The specific level of improvement will depend on the nature and severity of the deficiencies identified, the priority established for addressing specific deficiencies, the relative condition of other facilities in the system, and the resources available.

- **Evaluate Program/Project Alternatives:** A realistic estimate of the investment requirements can be made by evaluating the various program options defined both in terms of a resource level and the deficiencies to be addressed.
- **Select a Program Option:** The selection of a final program reflects several factors such as the resources available and is usually beyond the scope of most needs studies.

6.7.3 Needs Assessment and Estimates

The true condition of North America's infrastructure is not really known because assessment data are highly fragmented and there are major gaps in the available information. Before judgments about the level of resources to devote to infrastructure can be made, decision makers need to know the real impacts that varying levels of investment will have on them. It is therefore essential to have a needs assessment of the infrastructure. This would include the inventory and conditions assessment of the existing facilities and the future infrastructure based on future usage, and identification of the desired level or levels of maintenance and improvement (174).

The appropriate level of investment in any infrastructure facility will depend on many factors such as (174):

- Specific physical conditions;
- Quality of service provided by the facility;
- General condition of the rest of the system;
- The role and importance of the facility in the overall system; and
- The total resources available.

Traditional studies on infrastructure needs have been inappropriate since they (174):

- Have not reflected any policy choices or alternative service levels;
- Have been unrelated to what might actually be accomplished with less than the needed level or resources;

- Have defined projects that may or may not be cost-effective investments, irrespective of the actual budget available; and
- Have been no real guide to tough priority decisions on a facility-by-facility consideration.

The needs assessment becomes important in such cases. An important step in planning and management of infrastructure, needs assessment, is used for both programming and budgeting. The needs for new facilities are assessed along with the needs in the area of repair, rehabilitation and replacement - the three R's. It is " a current evaluation of the total needs for development and maintenance of a particular category of infrastructure" (106), and involves both the maintenance management and capital improvement processes, the identification of deficiencies and evaluation of alternative programs. The process involves:

- Development of an inventory;
- Condition assessment; and
- Identification of desired levels of improvement and maintenance.

According to the National Academy of Sciences, the needs estimates consider both economic and future scenarios. The information needed for the preparation of estimates include (106):

- Performance criteria;
- Economic analysis;
- Future analysis; and
- Evaluation of standards.

There is still a lot of room for improvement in the needs assessment process. Currently, a lot of needs assessments are handled very poorly and many decision makers simply do not follow them.

The Role of Standards

Standards play an important role in determining capital infrastructure needs. They (174):

- Help ensure that consistent approaches are used in improving similar facilities;
- Provide for compatibility of all elements in a system to ensure continuity of service;
- Offer potential cost savings by limiting the scope of potential improvements; and
- Provide for public safety through good engineering design.

The issue faced by many engineers is what level of service (including safety) should design standards reflect and how much flexibility should be allowed to tailor maintenance and rehabilitation strategies to particular facilities. There is therefore a need to reexamine current standards and the following questions need to be addressed (174):

- Have standards risen too fast to be realistic guides for the rehabilitation of infrastructure facilities in place for many decades?
- Do older facilities need to meet new facility standards?
- Have considerations of assumed risk and reliability created a large margin of safety for a given facility? and
- Is it better to improve a few facilities to stringent standards or many more to lower standards?

6.7.4 Condition Assessment

Infrastructure managers can better manage capital assets if there is information available on the capital condition and performance of infrastructure facilities. Currently, many condition assessment methods are based on subjective ratings and visual observations. There is a need to develop a systematic way of assessing the current situation of the existing facilities and analyze their needs.

The condition assessment information system need not be complicated. A simple version can serve the following purposes (100):

- Provide information needed to measure the extent of the deterioration of the facility.
- Identify potential areas of cost-savings (inventory reduction, coordination in the timing of repairs, etc.)

The information collected falls into two basic categories:

- Inventory measures; and
- Measures of condition or performance.

The applications of condition assessment to capital planning and budgeting are:

- Information on the extent of the inventory and its present condition helps planners establish the seriousness of the city's infrastructure needs; and
- Having updated information on the current state of the infrastructure, helps persuade politicians and the public of the need for increased capital spending in the rehabilitation and replacement of the infrastructure.

The applications of condition assessment to infrastructure management are:

- Day-to-day management of maintenance work forces;

- Computers programmed to pull out the relevant data from the work records to provide reports of the extent and location of the deterioration;
- Information for reports on the unit cost of repair; and
- Knowledge of the frequency and location of breaks improves the effectiveness of replacement and repair decisions.

Assessing the condition of the infrastructure includes the process of measuring the physical condition of facilities with clearly defined observable and measurable indicators. It is done using the following dimensions (174):

- **Safety and Structural Integrity:** All infrastructure facilities must be safe and sound for public use. Potential risk from structural failure varies widely by type of the facility, with bridges representing among the highest risks and sewer lines representing the least risk. Therefore, it is important to evaluate the structural condition and its importance to public safety.

- **Capacity:** Infrastructure facilities are designed to provide a certain level of service. For instance bridges are designed with capacities in thousands of vehicles per hour and water facilities are designed with capacities of millions of gallons per day. Therefore, facilities need to be evaluated to determine whether they have adequate capacity to meet a specific demand.

- **Quality of Service:** The quality of service provided by the infrastructure facilities is measured in a variety of ways. Street pavements are evaluated based on the smoothness of the ride, while measures of reliability of service can be used to measure the quality of water and sewer lines.

- **Role:** The role of an infrastructure facility is basically its relative importance varying from being minor to being absolutely essential. This depends on how the temporary loss of the facility affects the overall systems, the number of people/households involved, and the extent of the inconvenience.

- **Age:** Useful life estimates for infrastructure facilities vary greatly due to major differences in design practices, the loads and stresses experienced, environmental effects, and maintenance practices. Many facilities need to be replaced or rehabilitated before their theoretical useful life, while others may not require replacement for many years. Therefore, the actual operating experience provides the best indication of the facility condition.

6.7.5 Maintenance Management

An infrastructure maintenance management system typically performs five major functions (139):

- **Inventory and Condition Recording Management:** This function relates to the storage, retrieval and manipulation of information regarding the physical descriptions of the infrastructure facilities and their components. The data management capability can be supplemented by a full geographic information system (GIS) geographically display the system portions. Condition recording is part of the component level data to find such symptoms as corrosion, levels, types of cracking, etc.

- **Maintenance History/System Failure:** This comprises of preventive routine maintenance, testing and inspection of facilities, and repairs. It is very important to record maintenance events and inspections/testing data. The collection, storage, and manipulation of maintenance management history provides critical information for the purposes of capital improvement/maintenance planning.

- **Maintenance Management and Control:** The effectiveness of the maintenance organization, in terms of timely and cost-effective servicing of work orders scheduled or assigned, needs to be tracked. This can be done by collecting data related to work assigned/performed and control of maintenance resource utilization. This can help improve the efficiency of routine maintenance programs, as well as the organization's actions towards crisis situations.

- **Capital Improvement/Maintenance Planning:** The analysis of the rehabilitation or replacement of an infrastructure facility is done by the analysis of system status and the prediction of its future performance. Failure rates and loss of carrying capacity can be based on the maintenance history analysis. This planning model helps set up budget needs for routine maintenance and capital improvements projects, based on the detailed multi-criteria analysis. When the budget for public works are limited, planning can be useful for prioritization purposes.

- **Planning Maintenance Resource/Scheduling Maintenance Effort:** Planning the levels of resources (manpower and equipment) needed for maintaining infrastructure systems is an important part of preventive maintenance. It enables routine maintenance to be scheduled within the available financial resources.

Sources of data include (139):

- **Maintenance Records:** These records should be complete and if possible, categorized by maintenance type and diagnosis of problem when possible. This requires training the maintenance personnel for accurate maintenance recording.

- **Leak Detection Surveys:** These provide water loss and structural integrity information.
- **Customer Complaints:** These suggest operating problems.
- **Condition Assessment Surveys:** These involve surveys by video or video inspection of corrosion and other deficiencies.

The development of a maintenance management system can be phased over time. The first stage of development can focus on the inventory of facilities and their geographic referencing, maintenance history recording, or maintenance management and control. In the second stage, inventory and maintenance data can be entered or read from existing files. The development of a capital improvement/maintenance planning module and a module for planning maintenance resources and scheduling the maintenance effort can be undertaken simultaneously with the data-entry stage (139).

Table 6.2 provides a generically based listing of the types of activities that might be involved in a management framework for the full range of renewal activities for any infrastructure facility.

Table 6.2: Major Activities Associated with Infrastructure Renewal (109)

ACTIVITIES	NETWORK OR PROGRAM LEVEL OF MANAGEMENT	PROJECT MANAGMENT LEVEL
DATA	• Locational reference system • Facilities inventory • Field monitoring data on condition, flows, traffic, etc. Plus other data on costs, etc. • Data processing • Graphic and tabular presentation of status reports	• Detailed site data on structural materials, soils, unit costs, etc. • Subdivisions into project components, subsections, etc. • Data processing
CRITERIA	• Minimum level of service, structural adequacy, capacity, safety, etc. • Maximum user costs, maintenance costs • Maximum program costs/budget • Selection criteria (effectiveness maximization, etc.	• Maximum as-built variance from specified minimum structural adequacy or capacity etc. • Maximum project costs • Minimum interruptions (services, flows, etc.) • Selection criteria (minimum life-cycle costs)
ANALYSIS	• Current network needs • Deterioration predictions and future needs • Maintenance and rehabilitation alternatives • Engineering analysis and performance predictions • Life-cycle economic evaluation • Priority analyses • Evaluation of alternative funding levels	• Within-project alternatives • Testing (materials, structural components, etc.) and design analyses (behavior, deterioration ratio rates, etc.) • Quantity estimates • Life-cycle cost analyses
SELECTION	• Final priority program of capital projects • Final maintenance program and budget	• Best within-project alternatives • Maintenance treatments for individual sections, links, lines, etc.
IMPLEMENTATION	• Contracts schedule, tendering, awards • Maintenance schedule • Program monitoring • Budget and financial planning updates	• Construction activities, contract control (quality assurance, etc.) and as-built records • Maintenance activities, reporting and records (maintenance management) • Budget and schedule updates

6.8 COMPUTERS FOR MUNICIPAL INFRASTRUCTURE

There are many uses of computers in Civil Engineering. Most civil and structural engineers today use them for frame and truss analysis, hydraulic models, coordinate geometry, stress analysis, highway alignments, bridge analysis ands rating, etc. With the help of computers, civil engineers have also moved into three-dimensional plant design, digital terrain models, stress contours, artificial intelligence, Geographic Information Systems, air quality models, etc. Most engineers today also use some sort of word processing, spreadsheet, and database applications. Small firms can also afford a high level of computer automation, and compete with the big firms by using some or all of these methods (167).

An important task facing civil engineers is using the available computerized methods effectively in the office space, by investing in hardware and software with a strategy rather than purchasing individual applications for the project at hand (167).

Design software should be purchased to run "on top" of CADD software and the use of CADD systems purchases beyond drafting must be maximized. The two-step process of transcribing engineering sketches into drawings should be eliminated. Engineers and senior designers can use CADD for preliminary layout, analysis, and final design, and then CADD technicians can produce the final drawings with the same files (167).

6.8.1 Applications in Local Governments

Today's municipalities, public utilities, investor-owned utilities, and international airports are under intense pressure to reduce operating costs, improve customer service and make the most of the existing infrastructure. Reductions in staff and fiscal budgets are commonplace with many cities, municipalities, and public utilities considering consolidation, outsourcing of municipal services and privatization of operations and maintenance activities.

Service interruptions are costly. Lost revenues, costly repairs, property damage, and litigation often follow unforeseen water main breaks, gas leaks, pipe collapses, sewer overflows, and power outages. The critical factors facing public works and utility infrastructure managers are :

- Natural aging of utility infrastructure
- Soil erosion
- Capacity constraints
- Structural and material defects
- Excessive wear
- Equipment obsolescence
- Storm damage
- Hazardous dumping
- Industrial and motor vehicle accidents
- Contractor damage

- Corrosion
- Vandalism
- Inflow, infiltration, exfiltration
- Worn-out physical plant
- Competition from third-party contractors and private companies
- Environmental regulation

Deterioration of our nation's infrastructure, increasing demand for greater accountability, and the lack of readily available mission critical decision support systems, has created the need for advanced client/server asset management systems to help identify and prioritize repair, replacement, rehabilitation and renewal alternatives. Preserving the infrastructure to meet future needs requires accurate, timely information to support management decisions (107). Poorly maintained infrastructure is also the result of poor management practices. For instance (101):

- Public works expenditures are made without adequate management information about status, condition and the capacity of existing infrastructure.
- Many municipalities continue to reduce the funds available for maintenance.
- At times, public works projects are not viable in the first place since the practice of underestimating needs or poor management are not uncommon.

Computers are valuable in managing organizations and ensuring effective communication. The aim of using computers is to (106):

- Simplify decision making and problem solving;
- Make the team and individual worker more effective;
- Speed up the work;
- Effective communication; and
- Planning.

Over the past two decades, five processes have emerged as being useful in office automation and as compiled into today's integrated software:

- Word processing;
- Spreadsheet analysis;
- Data-based management;
- Graphics; and
- Communications.

Planning Systems

The planning process for infrastructure managers is more complicated because it involves the planning for maintenance and rehabilitation, and not the planning of new facilities. The manager needs to know the condition of the facility to plan the strategies for maintenance and rehabilitation, and to direct his or her resources. A physical inventory of the facility is not enough to "fix" it in a cost-efficient manner. It is also essential to know where exactly the problem lies. In order to have all this data available, two software systems are readily available; inventory systems and geographic information systems (GIS). Computer software applications used in the area of inventory location and identification include AM/FM/GIS. AM/FM refers to automated mapping and facility management (199).

Computers also used in the planning process for data base management to show resource and infrastructure availability for expanding or developing facilities. The following are some of the data bases needed to manage infrastructure (106):

- Geographic-based system inventory data base;
- Condition index data base;
- System water balance data base; and
- A data base for real-time system studies and management.

Data management systems for operating treatment plants and generating environmental information include:

- Various analysis and design data bases; and
- A financial data base.

Management Information Systems (MIS)

MIS is a network established within an organization to provide managers with information that will assist them in decision making (6). It is the development and use of effective information systems in organizations. The five major elements of MIS are (117):

- **Transaction Processing Systems (TPS):** They are the organization's basic accounting and record-keeping systems that help the organization conduct its operations and keep track of its activities. The important characteristics of the TPS are:
  - Supports day-to-day operations;
  - Processes high volume of data;

- Needs high performance due to the large amount of data;
- Requires high degree of accuracy;
- Processes data repetitively;
- Supports many users; and
- Is vulnerable to unauthorized or criminal activity.

- **Management Reporting Systems:** Produce reports to support business management. They are concerned with the management of resources involved in operations such as labor, money, materials, equipment, etc.

- **Decision Support Systems (DDS):** They are interactive (on-line), computer based facilities assisting human decision making. They support the solutions of problems that are less structured than those of a management reporting system, or TPS. A DDS is a collection of data and processing tools used to manipulate data to answer unknown and unexpected questions.

- **Communication Support Systems:** These systems use computers to assist in human communication throughout the organization. Examples of widely used communication support systems are:
  - Word processing;
  - Graphics;
  - Desktop publishing;
  - E-mail; and
  - Electronic conferencing.

- **Executive Support Systems (EIS):** EIS support information needs of senior executives by presenting highly summarized data. They usually produce reports in standard formats and often involve graphics.

Engineering Management Systems

Computer applications in the area of engineering management include (199):

- CADD systems (Computer aided drafting and design);

- Construction and project management;
- Pavement management systems;
- Vibration analysis for testing structural and mechanical integrity;
- Correlation analysis for failure projections; and
- Value engineering.

Environmental Systems

Most computer applications in the environmental systems relate to impact analysis. Those falling into the first category include (199):

- Stormwater runoff models for site detention basins;
- Air quality models;
- Traffic modeling; and
- Noise analysis.

Financial Systems

Spreadsheets are used for various purposes in the field of financial management, some of which are (199):

- Economic feasibility;
- Cost projections;
- Alternative financial solutions;
- Present value calculations;
- Privatization financing;
- Rate impact analysis and studies;
- Cost of service;
- Replacement versus rehabilitation analysis;
- Buy versus lease;
- Life cycle costing; and
- Risk assessment.

Maintenance and Operations Applications

Several maintenance management systems (MMS) packages are available for mangers to assist them with facilities such as wastewater treatment plants, buildings, roads, bridges, etc. They provide tools for (106 & 199):

- Preventive maintenance programming;
- Preventive maintenance scheduling;
- Field crew scheduling;
- Process control;
- Monitoring cost and productivity of resources used for maintenance;
- Condition information for maintenance and repair needs for budgeting;
- Repair records; and
- Spare parts stock card.

Operations management systems (OMS) are devoted to the facilities or the workers depending on the type of infrastructure. They tend toward emphasis on facility instrumentation and data collection, or toward some sort of work management information system. Operations managers need information and reports on the performance of the system.

6.8.2 Data Requirements

There are eight different types of data for information management with information technology (95):

- **Alphanumeric:** Consists of letters, digits, punctuation, and spatial characters, stored in database:
- **Spatial:** Used in location referencing and GIS
- **Graphical:** Consists of maps, charts and graphs.
- **Image:** Photographs.
- **Document:** Scanned images of contract documents, etc.
- **Audio:** Cassettes or similar tapes.
- **Video:** VHS or similar video tapes.
- **Time:** Gives attribute at one point in time.

According to Deighton, data must have the following five properties (64):

- **Validity:** The given value must be correct. Generally tested by comparing the given value with a range of acceptable values.
- **Integrity:** Two data values that profess to represent the same fact, must always be equal.
- **Independence:** Data should be stored as data and not as information.
- **Security:** Confidential and sensitive data must have restricted access and backups must exist to ensure data is never lost.
- **Accuracy:** The data must represent as closely as possible the actual situation at the indicated location and time.

6.8.3 Automating Inventory

Automated tools are necessary to speed collection and access to the large amounts of information required to describe the components of infrastructure. Databases can be powerful tools for maintenance, operations, and planning managers, but require a lot of time and effort to collect the information. This leads to the question: When is automating inventory/assessment appropriate? When there is a need for:

- Long-term usefulness of collected information; and
- Large number of things to be inventoried.

Tarhan and Jacobson feel that hand held computers for field inspectors to directly record information can greatly increase the efficiency of data collection and promote the following positive results (134):

- **Validity:** Development of automated data collection programs forces early decisions about exactly what information is required.
- **Consistency:** Automated inventory/assessments use pre-established classifications and definitions.
- **Repeatability:** Scripted inventory/assessments can be used by multiple inspectors, or over the years and yield similar results.
- **Usability:** Digitized data is uploaded into host PCs for import into standard database programs.

- **Quality:** Inventory/assessments are designed to require properly formatted answers to all appropriate questions and inspectors record results directly in digital format alleviating time-consuming and transportation of hand-written field notes.

6.8.4 Developing an Infrastructure Management System (IMS)

There are eight categories of public works infrastructure as defined by the National Council on Public Works Improvement (NCPWI), and they are competing for the limited funds available for their maintenance and rehabilitation. The categories of infrastructure include (64):

- Highways;
- Aviation;
- Mass transit;
- Water supply;
- Wastewater;
- Solid waste;
- Waterways; and
- Water resources.

The condition of these infrastructure systems can be compared based on the following four criteria:

- Physical assets;
- Product/service delivery;
- Quality of service to users; and
- Cost-effectiveness.

As the physical assets of all infrastructure, except airports, are steadily increasing, the overall quality of service of most infrastructure types is gradually deteriorating. It is very important to recognize the differences among the various types of infrastructure as well as their common elements.

There is a need to introduce infrastructure management Systems (IMS) at all levels of government. Each subsystem of the IMS is a decision support system for a different type of infrastructure. All subsystems have some common functions: planning, design, construction, evaluation, maintenance, and improvement. They also have some common elements such as inventory, measure of quality of service, needs analysis, project selection, and impact of the various funding levels. The following specific issues pertaining to each subsystem may be considered (64):

- Capital investment requirements
- Safety implications; and
- Criticality of service.

Within each infrastructure subsystem, relative benefits of "structures" such as freeway versus arterials can be addressed. These microscopic and macroscopic aspects of the infrastructure can be addressed by an individual management system such as a GIS (Geographic Information System), and/or by an IMS.

Universal Location Referencing System

Data for an integrated IMS comes from many different independent sources such as traffic departments, planning departments, and water and wastewater departments. Data independence is required for the data to be placed into the database independent of any perceived infrastructure management applications. Coordination of data management is necessary in case the IMS becomes more and more complex. A consistent location referencing system is required to better coordinate data management of numerous subsystems. If a different location referencing system is adopted for each subsystem, transferring data from one subsystem to another becomes extremely difficult.

There are several methods of identifying the locations of infrastructure facilities. Common elements of any location referencing method in the infrastructure network include:

- Identification of a known point;
- Measurement from the known point; and
- Direction of the distance measurement.

It is important to have a universal location referencing system since differences in the present location referencing methods make interfacing and communicating among various infrastructure groups quite difficult. The GIS are being considered by many local public agencies as a spatial data integration and presentation platform for IMS. While in some GIS-based IMS applications, the location referencing system include both a linear sequenced reference method along the infrastructure network and a coordinate reference method for locating other infrastructure features, the cross-referencing capability between the coordinate system and the linear referencing system has not been established (64).

Consistent Infrastructure Condition Evaluation

The evaluation of the condition of the various infrastructure types is an essential input to IMS. There are different methods of evaluation for different types of infrastructure. For instance, water-pipe breakage can be located through water audit procedures, while cracking and spalling of pavement can be located using a video camera. Manual techniques are most commonly used for condition evaluation, however, they are subjective and inconsistent. Automated techniques applying various sensors are becoming popular in evaluation of infrastructure conditions (64).

Infrastructure Data Transformation

The performance of infrastructure is a collection of infrastructure conditions over time. The new automated inspection methods have made a large quantity of data available for the analysis of infrastructure performance and these enhanced data-collection capabilities can be used to improve the infrastructure performance models. In developing an IMS, performance models can be incorporated into the decision making process using the following predefined functions:

- Selection matrices;
- Regression curves; and
- Expert decision rules.

In order to transfer different sets of data from the various infrastructure types, an IMS should have cross-referencing capabilities so that the benefit generated for each dollar spent can be compared across different types of infrastructure. The quality of service to the public of each infrastructure type should be evaluated for budget allocation keeping in mind their interactive nature. Therefore, the totally integrated IMS should be designed to take all the components of the infrastructure into consideration during the analysis (64).

Automated Mapping (AM) With Dynamic Segmentation

Infrastructure can be represented graphically as a set of networks that includes pipes, highways, roads, etc. A network is composed of nodes and links. A spatial database can be assembled from simple lines linked together to form a complex infrastructure network. Each link would have attributes such as pipe diameter, number of lanes, etc. Automated mapping (AM) is one tool used to represent infrastructure graphically. It can be considered a basic tool that assists a user in the following activities:

- Linking the data in the database to a base map of the infrastructure network;

- Accessing the infrastructure data through maps;
- Displaying a variety of data on a map of the infrastructure network;
- Providing data display and data editing functions through graphics; and
- Creating maps of the infrastructure management reports.

AM deals with the geometry and placement of spatial objects and can view infrastructure in a geographical context and graphically examine relationships between the infrastructure features. Topological relationships among the various infrastructure features can be handled through the use of a one-and-a-half-dimensional linear referencing method using dynamic segmentation. Topology is the study of surfaces. Dynamic segmentation is the ability to cross-reference data from one type of infrastructure network with another and can provide an IMS with the ability to cross-reference the data describing one type of infrastructure with the data describing another type of infrastructure. Dynamic segmentation allows the user to do the following:

- Cross-reference data from one type of infrastructure network with another;
- Process data form many different independent infrastructure data sources; and
- Treat various kinds of infrastructure data in different mathematical ways.

AM can retrieve and attribute data from the infrastructure database and make various maps of the infrastructure according to the attribute data. It can also be used as an aid for visual analysis of large infrastructure databases, and it can produce maps of infrastructure rehabilitation locations (64).

Geographic Information Systems (GIS)

Geographic information systems are created from the use of several technologies such as digital mapping, data processing, engineering and management systems to manage geographic information. It integrates both graphic and non-graphic information related to geographic maps, land reference plans, and street and water mains plans used for the management of municipal services. Before GIS systems are defined further, it is important to understand digital mapping.

Digital mapping is a tool based on computer-aided design (CAD) technology that map makers and engineers use to produce maps, and design and manage structures built on the area represented on those maps. Digital mapping has the following advantages over manual mapping:

- Corrections are easily made;
- Maps can be divided into layers according to the type of information (street, house, etc.);
- These layers can be combined or grouped for analysis;

- Symbols can be altered to suit the needs of the user; and
- Maps can be altered to suit the needs of the user.

A GIS system must incorporate the following:

- A database;
- A digital map;
- Data processing ability;
- Communication ability; and
- Decision-making assistance.

The system has to be able to store a process a vast amount of data and provide information requested by the user. In addition, the system must be able to differentiate between graphical and non-graphical data, for example:

Graphical Data	Non-Graphical Data
• Property lines	• Street names
• Stormwater networks	• Civic addresses
• Sewer networks	• Zoning
• Public right of ways	• Sewer diameters
• Land parcels	• Manholes sizes
• Building locations	• Types of permits
• Sidewalks and streets	• Assessment
• Lakes and rivers	• Soil utilization

The advantage of such a system is that it can reduce the time required to search, gather and process data, enabling municipalities to make decisions more quickly and completing projects on time. In addition, the right information can be accessed at the right time for such municipal services as:

- Preparing the assessment roll;
- Fire prevention;
- Optimizing police patrols; and
- Planning ambulance and other emergency dispatch services.

To apply GIS in infrastructure management, infrastructure facilities inventory must be entered into the system. This would require the complete inventories of streets, wastewater mains, lighting networks, signs, sidewalks, etc. In addition, all contract files and historical records also have to be input. These data are very important for infrastructure planning, budgeting and maintenance management. Once this information is available in the system, the public works manager or engineer can plan strategies for infrastructure renewal and prioritize the areas of the greatest need (202).

GIS application to infrastructure management covers the following activities (202):

- Planning and design of infrastructure;
- Preparation of engineering plans and estimate issue;
- Operational management of municipal services such as water, sewer, and traffic control;
- Maintenance of urban infrastructure including planning of preventive maintenance, maintenance of street paving, bridge structures, etc.; and
- Project management and control including project management for infrastructure construction and project coordination.

In the GIS, relationships can be computed from the coordinates of the infrastructure features, such as two highway lines intersecting or overpassing. These relationships can then be stored in spatial database as attributes. If such spatial relationships are stored in a database, this spatial database is called topological. The advantages of creating and storing such topological relationships are (64):

- Efficient storage of the spatial data;
- Faster processing of the spatial data;
- Ability to process the larger data sets; and
- Capability to conduct spatial analysis.

A GIS can also define new objects by buffering a polygon overlay. It can perform two-dimensional spatial analysis that can relate polygons, lines, and points through spatial location by using topology. Examples of analysis functions available for specific GIS operations include:

- Measurements;
- Coordinate transformation;
- Object generation;
- Attribute modification;
- New object creation;
- Line smoothing;
- Statistics computation;
- Topological overlay; and
- Network analysis.

The decision on whether to use GIS or AM depends on whether on not the spatial analysis capability is needed for IMS (64).

Decision Support Systems

Due to the recent advances in computer technology, there has been a rise in the application of electronic computing in information processing. Infrastructure decision makers require historical data and continuing improvements in problem-solving techniques to allow long-term investment and short-term operational enhancements to meet their needs.

A decision support system (DSS) incorporates both data and knowledge that can improve the effectiveness of the decision and the efficiency of the decision making process. The simplest DSS provides data for decision making, relying primarily on a computer based information storage system such as databases, along with the supporting numerical and graphical programs providing correlated information that is difficult to deduce by looking at the retrieved data (107).

A successful DSS supports decision makers by organizing knowledge about ill-structured issues, formulating the decision situation, identifying appropriate objectives, and generating alternative courses of action that will resolve the needs and satisfy the objectives. DSS, incorporated with decision methodologies enables a systematic approach for processing information for management decisions.

Executives in private industry businesses and public agencies make decisions about facilities by considering financial, operational and organizational issues, while the design and construction professionals focus on the technical issues related to these facilities. Information about all aspects of an organization should be available to all decision makers at all times. This can be achieved with information technologies, including methods, techniques, software and hardware to create seamless decision support environments. These decision-support systems must be developed by multi disciplinary teams including owners, engineers, architects, builders, computer scientists, cognitive scientists and economists. In addition, these systems should be directed to the reuse, recycling or reconfiguration of existing tools and software to obtain quick and effective results. Since in the past, the end users of the built facility have been ignored, business and public bodies should be involved in the planning and the dialogue that takes place at the initial stages. Decision support systems must be utilized to regulate logical and clear methods of decision making to ensure the following institutional goals (36):

- Productivity;
- Bottom line; and
- Sustainability.

6.9 ETHICS

" Ethics deals with defining right conduct" (106). It is a critical part of management and is concerned with (6):

- Good behavior; and
- Our obligation to consider our own well-being, and that of others.

In business, ethics can be defined as, "the capacity to reflect on values in the corporate decision-making process, to determine how these values and decisions affect the various stakeholder groups, and to establish how mangers can use these observations in day-to-day company management" (6).

Although this is important in all organizations, it is more critical in the field of infrastructure management because a lot of public money is involved and the main goal of infrastructure organizations is to provide basic human services to the general population. Hard earned money of the taxpayer should be well managed so that the most can be achieved with it. Most of our current infrastructure problems are not due to the lack of financing, but due to corruption and mishandling of public money.

6.10 SUMMARY

In the design and construction of infrastructure, a proper maintenance schedule should be devised that is then followed precisely. The management of infrastructure plays a crucial role in its maintenance and upkeep. Had our infrastructure been managed properly, we would not be in as big a mess as we are now. Public works agencies must reevaluate their decision-making process for capital and maintenance investments so that the best allocation of resources is made to projects. It is critical to get maximum value from available funds with substantial needs and limited resources. In addition, to manage our infrastructure, it is necessary to perform needs assessment and condition assessment studies. Otherwise funds will not be properly allocated and the actual condition of the municipalities infrastructure will be unknown.

Most municipal engineers lack sufficient background and education in the required management techniques and have in many cases, not been given the right tools to get their work done. In addition, the older staff in public works departments are usually rigid and unwilling to change and adopt new management techniques, therefore the ideas must travel from the bottom up. New staff may be more aware of the current situation and open to applying new technologies and should therefore be allowed to contribute to the decision making process. If municipal officials do not back up the municipal engineers who want to innovate and take action needed for the deteriorating infrastructure, it is the municipal engineer's duty to educate them and thoroughly explain the consequences of their inaction.

Infrastructure managers need to be leaders, supervisors and technical managers. Developing an effective management approach is a long-term way to handle a problem as large as our current infrastructure crisis. Engineering skills alone will not be adequate to resolve this crisis. We need to examine skills needed to manage infrastructure and how they should be applied. Engineering skills need to be complemented by solid management skills.

7.0 FINANCING INFRASTRUCTURE

7.1 INTRODUCTION

The different orders of government- federal, provincial and local - play an active role in the financing of urban infrastructure. Each government is responsible for the construction, operation and maintenance of some aspect of municipal infrastructure. All three levels of government have contributed in a significant manner to the deterioration of our infrastructure. Decline in provincial and federal grants along with the reduced use of debt financing has led to the rapid deterioration of municipal infrastructure over the past few decades. After all, a drastic decrease in funding by the provincial and federal governments put a great deal of pressure on the municipalities, which began to experience financial constraints and as a consequence they made major cuts to their public works (maintenance and repair).

Infrastructure projects involve higher risks than other activities, which leads to public involvement in related decision making. Coordination by the public sector may also be required since each project is part of a large system, such as a single road forming part of a region-wide road network. Infrastructure financing is unique compared to other operations of government because (210):

- They are large, up-front investments requiring significant capital outlays;
- Infrastructure systems have a long economic life; and
- There is interaction with other infrastructure projects.

Our infrastructure has deteriorated to such an extent that a considerable amount of financial investment is required to upgrade it to an acceptable level. Expenditure on infrastructure by all levels of government has decreased steadily and any increase has resulted in higher municipal taxes (127). To most public works officials, the infrastructure financing problem consists of finding enough money to pay for the maintenance and new investments required for infrastructure. Since the different levels of government do not have the financial means, or the political will to upgrade our infrastructure, and raising municipal taxes to meet that goal is politically unacceptable, alternative methods of financing infrastructure need to be examined seriously. There are several alternatives to municipal taxes available and some are already being practiced by several municipalities. This chapter provides an overview of the current and alternative financing mechanisms available.

7.2 CURRENT TRENDS

According to the 1995 McGill/FCM survey, the most often used source of revenue for the operation of infrastructure facilities are general taxes and user fees. For rehabilitation and replacement of infrastructure, the most often used sources of revenue are general taxes, debt financing, user fees and provincial subsidies. The sources of revenue for operating the different infrastructure facilities in Canada are shown in Table 7.1 and the sources of revenue for rehabilitation and maintenance of the different infrastructure facilities are shown in Table 7.2. The percentages shown represent the number of responses. These results show that most local governments are not aware of or not exploring alternative financing methods. In addition, many still rely heavily on provincial and federal subsidies, which are in a short supply, therefore they must investigate the feasibility of using alternative financing methods to eradicate the infrastructure crisis (209).

Table 7.1: Sources of Revenue for Operation of Infrastructure Facilities in Canada (209)

Facility	Gen. tax rev	User fees	Reserves	PPP*	Debt financing/ Borrowing	Prov. subsidy	Fed subsidy
Bridges	66.2%	0.5%	0.1%	0.0%	2.9%	30.1%	0.3%
Community and social services	39.2%	25.0%	5.6%	4.3%	1.4%	23.6%	0.8%
Curbs	67.8%	0.9%	0.9%	0.1%	2.2%	27.9%	0.2%
Hazardous waste	55.7%	34.1%	6.0%	0.4%	0.5%	3.3%	0.0%
Parks and recreational facilities	35.6%	31.1%	7.7%	14.0%	2.8%	6.5%	2.2%
Public buildings	69.2%	13.4%	11.2%	0.4%	5.0%	0.5%	0.3%
Roads	58.1%	1.1%	3.3%	0.1%	4.2%	32.8%	0.4%
Sanitary and combined sewers	27.2%	39.6%	9.2%	0.1%	11.0%	9.7%	3.2%
Sewage	25.8%	43.5%	9.2%	2.8%	14.2%	4.5%	0.0%
Sidewalks	81.8%	1.9%	1.4%	0.2%	4.6%	9.7%	0.4%
Solid waste	32.8%	40.3%	16.4%	6.3%	1.8%	2.2%	0.0%
Storm	52.6%	12.6%	7.8%	0.4%	8.8%	17.4%	0.4%
Transit	36.1%	32.0%	0.0%	3.2%	3.0%	25.6%	0.1%
Water Distribution	9.7%	63.0%	9.5%	0.1%	10.8%	3.7%	3.2%
Water Supply	12.0%	63.6%	9.1%	3.2%	10.8%	1.2%	0.1%

• Public-Private Partnerships

Table 7.2: Sources of Revenue for Rehabilitation and Replacement of Infrastructure Facilities in Canada (209)

Facility	Gen. tax rev	User fees	Reserves	PPP	Debt financing/ Borrowing	Prov subsidy	Fed subsidy
Bridges	27.4%	0.0%	7.6%	2.3%	27.6%	28.9%	6.1%
Community and social services	25.0%	5.1%	15.6%	7.8%	25.0%	17.7%	3.7%
Curbs	33.7%	1.4%	6.5%	6.1%	24.3%	22.9%	5.1%
Hazardous waste	31.3%	28.1%	5.4%	1.1%	23.5%	7.4%	3.3%
Parks and recreational facilities	24.1%	4.6%	15.5%	12.7%	18.9%	13.9%	10.3%
Public buildings	29.9%	2.8%	16.6%	6.8%	35.1%	5.7%	3.0%
Roads	26.8%	1.0%	7.3%	4.0%	24.2%	28.6%	8.1%
Sanitary and combined sewers	14.4%	21.1%	18.7%	1.7%	26.7%	13.4%	4.0%
Sewage	9.1%	18.8%	18.8%	0.0%	29.3%	14.5%	9.5%
Sidewalks	36.0%	1.1%	7.8%	8.4%	26.1%	14.2%	6.4%
Solid waste	20.2%	25.4%	17.1%	2.0%	30.7%	4.4%	0.1%
Storm	26.7%	14.9%	7.2%	3.9%	26.7%	17.5%	3.1%
Transit	24.2%	20.2%	4.9%	3.5%	25.2%	21.8%	0.3%
Water distribution	4.3%	33.1%	19.0%	1.8%	27.3%	9.1%	5.5%
Water supply	3.2%	31.2%	21.7%	1.7%	31.9%	7.4%	2.9%

7.3 TAXES

The property tax is the largest source of local income for municipalities. It is levied on residential, commercial and industrial properties. A tax rate is set by the municipality and applied to the assessed value of property. In most cases, commercial and industrial properties are subject to higher taxes than the residential properties.

This is also a visible tax since, unlike the income tax, it is not withheld at source, the taxpayers are required to pay it directly to the local government, and it finances services that are visible such as roads and transit. Its visibility makes the local governments accountable. The tax has been criticized for being unrelated to the ability of the taxpayers to pay, unrelated to the benefits received from the local governments and inelastic due to the fact that it does not increase over time.

Since most municipalities are reluctant to borrow, they use property taxes to finance their infrastructure needs. However, this tax is less appropriate for financing infrastructure with a long expected life since that would mean that the current and previous taxpayers are paying for infrastructure that will largely be used by future generations. The use of property taxes for infrastructure also implies that infrastructure has to compete for limited funds with operating demands for services such as the police, fire, and other local services (210).

7.3.1 Special Assessment and Local Improvements Charges

Special assessment charges are imposed on residential, commercial or industrial properties to pay for additions or improvements to the existing infrastructure facilities bordering on those properties. Although there is little documentation of their use, they have been widely used in Canada to finance capital expenditures such as paving and re-paving of streets, installation or replacement of watermains and sewers, construction of sidewalks, etc.

Their advantage is that many of these works increase the property value of the nearby land, directly benefiting the owners. This enables the municipalities to recoups their costs from the properties directly benefiting from their expenditure. Therefore, this form of financing should be used only where the beneficiaries are easily identifiable. Otherwise, it would be necessary to finance a portion of the costs from the general municipal revenues such as the property tax (210).

7.3.2 Land Value Capture Taxes

A land value capture tax is charged in a selected area to pay for a public improvement project that increases the property values resulting from the ability to develop land for commercial or residential use. Further empirical work is needed to determine how much infrastructure investment affects land values, so that local governments can easily determine a land value capture tax. Properties within the zone of influence of that infrastructure facility may benefit in several ways:

- A property that leases space near the project can increase rents due to the increase in the desirability of the location. Property values increase even if the owner makes no improvements to the property;
- A previous ceiling of development on the properties within the zone of influence may be relaxed by the municipalities; and
- Municipalities may allow properties to increase densities beyond the ceiling if they provide certain facilities or services.

Density bonusing is one form of land value capture in which the municipality permits a rezoning of land to a more valuable use, such as greater density or height, in return for the developer providing various facilities, or infrastructure. It taxes the developer on the basis of the value added to his/her property from the increased density. This tax has been criticized widely since it results in bad planning decisions (210).

7.4 DEVELOPMENT CHARGES

Development charges, which are also known as impact fees, are used to finance new infrastructure facilities such as water supply, sewage collection and roads. This system of financing can also be applied to re-zoning and building permits.

Development charges can replace property taxes from the whole municipality since only those benefiting from new infrastructure have to incur the costs. For instance, when a road is built in any new development, only the new property owners bear the costs of its construction. Usually developments consisting of single-family units are subject to development charges for they require just as many essential facilities as high density dwellings where the turnover is higher due to a larger segment of the population being serviced at the same development costs.

Development charges are usually paid almost immediately at the issuance of the building permit. It is usually the developer who incurs the initial cost and later transfers that cost to the new owners. The cost transferred to the new homeowners may be insignificant depending on the cost of the house. More expensive houses will not be affected as much, since the development cost will only be a fraction of the total cost. Cheaper homes face a comparatively larger impact, although this may be offset by increasing the housing density.

It is important to note that development charges are only suitable for the construction of new facilities and only cover the cost of constructing the new facility and not maintaining it. Other methods of financing have to be sought for their maintenance. These charges are not suitable for new facilities that serve the entire community such as schools, but for facilities that serve a small portion of a community.

There are some disadvantages to development charges, since in some cases they may hinder new developments. Some developers may prefer to invest in development elsewhere. It is for this reason that these charges must be applied in municipalities that are undergoing considerable growth. In addition some find it unfair to charge new property owners only for facilities such as roads which are also used by other residents of the municipality (127).

7.5 SPECIAL DISTRICT FINANCING

This form of financing is similar to the development charges and it is used to finance hard facilities that benefit a limited number of identifiable users (192). It is used in conjunction with the development charges or other financing mechanisms to recover the costs of new infrastructure facilities. The process involves the creation of any of the following (127 & 191):

- Special district;
- Special purpose authorities;
- Public corporations
- Local improvement areas; or
- Community rehabilitation districts.

The need for special districts usually arises when (191):

- The financial or administrative capabilities of local municipal governments are constrained;
- Local governments are unable to provide a high or adequate level of important services such as roads, sewers and water utilities to their residents;
- Larger communities are reluctant to expand existing systems to meet new demands; or
- Municipalities have limitations on how much debt they may incur, fixed by the Provinces through the Municipal Board.

The main difference between the development charges and the special district financing is that with the latter, new homeowners are not affected as much since they are not required to pay the cost of the new facilities in advance. With special district financing, the cost of construction is financed over the life of the new facility. In addition, unlike development charges, this form of financing can also be used for maintenance of the existing facilities.

Special districts are governed by elected boards that determine their own budgets, taxes, and service charges, employ staff and operate infrastructure facilities. Special districts are only formed when there is a demand for infrastructure and only the principal beneficiaries of the new facility pay for its cost. Revenues are generally assured, depending on the size of these districts, since the homeowners are willing to pay for the infrastructure over the period of its normal extended life (191).

However, although this form of financing is quite effective in paying for the cost of infrastructure construction and at times its maintenance, it can lead to large and complex administrative units in local governments. At other times, local government officials point out that these special districts have too much power and take away a lot of control that should be in the hands of only the municipal officials. In addition, one should note that special districts *can* fail. Their success is not always guaranteed. There have been cases where they have gone bankrupt.

7.6 USER FEES

The user fees are used to finance infrastructure by making the direct beneficiaries financially responsible for it. This implies that a portion of the society is excluded from using facilities financed by user fees if they cannot afford them, as they have to pay each time the facility is used.

Examples of infrastructure facilities financed by user fees are:

- Roads and bridges;
- Transit systems
- Water; and
- Electricity.

7.6.1 Transit and Road Pricing

User fees for roads and bridges can be in the form of (31):

- Tolls;
- Gasoline tax; and
- License fees.

Tolls are used extensively in the U.S., however, they are not so prevalent in Canada. They were used on Quebec highways in the 1970s, but were later removed due to the resulting traffic inconveniences (31). Even if the collection points were posing a hazard, they could have been improved and corrections made, because their removal resulted in a considerable loss in revenues. It should be noted that the system works effectively in the U.S. where the volume of traffic far exceeds that in Canada.

Tolls on bridges and highways are still collected but unfortunately their elimination can be used as an issue to attract votes in an election campaign. For instance, removing the toll on the Champlain Bridge in Montreal became part of the provincial party's campaign and was removed when the party came to power. This was a very bad judgment call because it resulted in a considerable loss in revenues which were needed for the ongoing maintenance of the bridge and the major rehabilitation that the bridge recently underwent.

Urban transit is always financed using user fees, but these constitute only a small portion of the total operating and maintenance costs, because the transit systems are subsidized heavily by the local and the provincial governments. In practice, transit facilities are priced below the cost required to maintain and operate them because there is a need to divert the general public from using their cars, and pricing using marginal costs (full cost of the facility) would make public transit an unattractive option (127).

Different forms of financing can be applied to the transit system. A fixed fee can be charged for each time the facility is used, which is the most common practice, or a variable rate can be applied depending on the time of day with rates being higher or lower during rush hour. Another form of practice would be to charge only the non-users to encourage them to use the public transit, thus those using the public transit are not penalized for doing so.

Research is needed to determine the correct subsidy or fare for transit systems. What portion of the costs should be paid by fares, and what portion by property taxes, and what portion should be subsidized by provincial grants? (210)

The Institute for Transportation identifies the following key issues and considerations in analyzing toll costs (210):

- What type of toll barrier system should be used?
- How many barriers are necessary?
- Where should the barriers be located?
- What toll rate structure should be used?
- How will traffic respond to the toll rate structure? How will traffic grow?

7.6.2 User fees for solid waste

A few Canadian municipalities, particularly those facing limitations on taxing ability, have begun to apply user fees for residential solid waste collection. In Victoria, British Columbia, the fee increases with the volume of solid waste collected. There are at least 23 variable curb-side disposal fees in place in Ontario alone. More empirical work is required to determine the impact of fees for garbage collection. There is no assessment of the impact of user fees on waste diversion, illegal dumping and the need for landfill sites. According to a few case studies, curbside disposal fees result in waste reduction, however the degree of diversion depends on community characteristics such as the socio-economic factors (210).

7.6.3 Water Pricing

Water is also financed through user fees in many communities with rates varying considerably from one municipality to another. The Canadian rates are in general very low and this results in Canada having one of the highest rates of water consumption per capita in the world. The different types of rates used in Canada are: (31)

- Flat rates
- Declining block rates: Charge per unit of water declines with increasing water use.

- Increasing block rates: Charge per unit of water increases with increasing water usage.
- Constant rates.

More municipalities should use increasing block rates to encourage water conservation which in turn reduces the amount of wastewater. As most municipalities charge flat rates, the public is less inclined to conserve. Increasing block rates affect those using the greatest volume of water. However, the process of implementation may not be simple because if the surrounding municipalities do not implement them, then the residents may prefer to live there. In other words, the practices of the surrounding municipalities play an important role in the choice of water rates.

Decreasing block rates are an inefficient practice because they encourage over-consumption and wastage since the price falls as consumption increases. As consumers are inclined to use more and more water, the operating costs at the water treatment plants increase and sewers overflow. In addition to an increased load at the plant, the revenues fall.

Another method of charging for water while encouraging water conservation, is metering. Each household is charged according to the amount of water consumed which in turn produces less wastewater since there would be an incentive to consume less water than when there was a flat rate for every household.

Municipalities can also fix a higher fee for water usage in the summer over that imposed in winter to encourage water conservation. Table 7.3 shows some effects of metering on water use. Based on theses results, metering is a useful tool for water efficiency and municipalities should look into implementing it.

Table 7.3: Empirical Studies of the Effects of Metering on Water Use in Canada (210)

Location	Impact
Etobicoke, Ontario	Water use 45% higher in unmetered areas than in metered areas of comparable assessment.
St. Catharines, Ontario	Consumption dropped by 11% following metering but rebounded because prices were kept low. Two years later, water usage was higher than before metering.
Alberta	10 to 25% drop in water use following meter installation.
Peterborough, Ontario	10% reduction in water use predicted following meter installation.
Calgary, Alberta	Unmetered water use 65% greater than in metered residential areas.
Selected Canadian Municipalities	Residential water consumption was twice as high in unmetered communities as in metered communities.

7.7 BONDS

Bonds can be used to finance capital projects when municipalities are trying to avoid long-term debt financing. Bonds are useful for large communities that have good bond ratings and therefore lower interest rates. Bond financing is generally applied over the period of the useful life of the facility. There are several types of bonds available for financing infrastructure (127):

- **General Bonds:** These are commonly used to finance infrastructure that benefits the whole community, such as water and waste treatment facilities, public schools and municipal buildings, fire stations and police stations, where a fee system is difficult to implement. They are secured through the general taxes. Fluctuations in interest rates can leave the municipalities vulnerable to high interest rates. If these bonds are over-used, the property taxes may have to be increased; this also affects the community bond rating.
- **Tax Exempt Bonds:** In this case, the interest income is not taxable by both the personal and corporate income tax systems and therefore requires the permission of the federal and provincial governments. These bonds enable municipalities to borrow at lower rates than the regular bonds. They are used mostly to finance facilities such as water and sewage treatment plants.
- **Revenue Bonds Financing:** These are used mostly to finance facilities that generate revenues like the transit systems. They are secured by future revenues and user fees. The fact that these bonds have user fees as collateral, render them as one of the most efficient bonds.
- **Public Lease Revenue Bonds:** In this case, the private sector organizations become the owner of the facility being financed. These firms make installment payments to the public development authority that issues the bonds, and then they lease back the facility to the municipalities. The municipalities can purchase the facility at the end of the lease. This option is quite attractive to the private sector because they are eligible for investment tax credits and rehabilitation credits. These bonds are used mainly to finance facilities having long term uses such as water and sewage systems.
- **Bond Banks:** These bonds are used by small municipalities which cannot issue bonds on the financial market due to a low credit rating, or no rating at all. With bond banks, the municipalities can:
    - Have access to a higher credit rating;

- Can diversify the potential risk;
- Reduce transaction costs; and
- Have access to the major bond markets.

7.8 FUNDS

Revolving Loan Funds

These funds are government money to fund certain types of infrastructure, in the form of grants or lower interest rates. At times, no interest needs to be applied since there are no debt obligations at all. They are a very reliable source of financing for municipalities. They aid municipalities by financing (93):

- Construction/renovation;
- Buy/refinance certain municipal outstanding debt;
- Guarantee/purchase insurance;
- Revenue/security for payment of the principal and the interest on municipal bonds; and
- Offer loan guarantees for similar revolving funds.

Trust Funds

Trust funds are taxes collected and placed in the funds for the maintenance and construction of certain infrastructure. A good example of this would be the gasoline tax which provides funds to maintain the road system. These funds are quite effective since their management is made easy due to the fact that the government has the exact knowledge of the amount of funds collected and the expenditures can be traced easily (93). However, it should be noted that these funds are rare and all governments take in more from gasoline taxes and licensing fees than they spend on roads.

7.9 PRIVATIZATION

When it is impossible to generate enough revenue or collect enough funding to build a new facility and maintain it, privatization is an option that can be used. Privatization brings in private financing for the infrastructure. Private companies design, build, own, operate and finance the facility. Examples of facilities that have been privatized are roads, bridges, tunnels and transit systems. Now even water and wastewater treatment plants, sewers and solid-waste resource facilities are privatized.

Privatization of infrastructure is thought to save costs since private firms are normally more cost-efficient. However, consideration must be given to the monopolization of infrastructure which must be avoided at all costs. Some of the reasons for which governments may be attracted to privatization are (204):

- Capital cost-savings;
- Lack of expertise;
- Inefficient facilities; and
- Operating cost-savings.

With privatization, the users wind up paying for the full cost of the facility as there are no subsidies involved. However, this may be unfair to low-income people who end up paying the same amount as high-income families.

Privatization also translates into full responsibility for the risks undertaken by the private firm. In addition, these companies must comply with several regulations, which can be quite costly to implement.

The benefits of privatization are (175):

- Better efficiency in production;
- Reduction of waste;
- Better access to capital markets; and
- Improvements from competition.

The disadvantages of privatization are (175)

- Need for standardization across the country;
- Reduced ability to achieve social goals;
- Difficulty in providing equal access to all;
- Higher cost of private sector financing; and
- Potential for high and unfair pricing.

7..9.1 Public-Private Partnerships (PPP)

This financing mechanism involves both the private and public sector. Depending on the agreement reached between the two parties, the private firm usually designs and builds the facility, operates it, leases it or purchases it and then transfers it to the public sector. There are several types of public-private partnerships (30):

- **Operate:** In this option, the private firm simply operates the infrastructure facility for which it is paid a fee by the government. The government is responsible for the capital costs. Examples of such operations are prisons, garbage collection and sewage plants.

- **Build:** This is the most common type of partnership where the private sector builds the facility according to the guidelines set by the public sector and then turns it over to the public sector for operations.
- **Build and Operate:** In this type of partnership, the private firm provides the capital financing and builds and operates the private facility. The operation is controlled by a regulating body to avoid the problems associate with monopolies. The user fees and the levels of service are highly regulated. Examples are telephone, electricity and cable television companies.
- **Lease and Operate:** The facility is leased by the private firm from the public sector and operates it by charging user fees. Examples are airports and water filtration plants.
- **Purchase and Operate:** The private firm makes a lumpsum payment to the public sector at the beginning of the partnership. If a monopoly is involved, there are rules and regulations that need to be set for a minimum level of service and maximum user fees. If no monopoly is involved, then it is simple privatization.
- **Purchase, Build and Operate:** Along with purchasing and operating the facility, the private sector is also required to develop, enlarge, or maintain it.
- **Lease, Build and Operate:** The private firm leases the facility and is required to build new or expanded facilities and operate them for a number of years. An example would be a highway built or expanded by the private sector and operated for a number of years as a toll road.
- **Build, Transfer and Operate:** The private sector builds the facility and is responsible for all its financial costs. Upon completion, the private sector operates the facility to recover its capital costs and the ongoing operating costs. The public sector takes over as owner either upon completion of the construction, or at the end of the contract, or when the capital costs have been recovered.
- **Build and Transfer:** The private sector builds the infrastructure and transfers its ownership to the public sector for operations. Examples are construction of roads,

curbs, sidewalks, etc., which are constructed on private land according to the government specifications and then turned over to the government for their operation and maintenance.

Price Waterhouse notes that structure of PPP depends on the way in which risks are shared. The more the risk the private sector shares, the greater the returns it expects. It has identified the following types of risks associated with PPP (210):

- **Project Risk:** The more complex the project, the greater the risk. Development of infrastructure may be more costly to develop than originally planned due to construction delays and unforeseen technological difficulties.
- **Operating Risk:** The facility may not operate as planned, with the consequent cost overruns.
- **Market Risk:** The demand for the service may be lower than planned, resulting in lower revenues. This risk is significant for facilities relying on user fees.
- **Regulatory Risk:** Changes in regulation may occur and delay the project, increase costs or reduce the benefits to users. This risk is significant for projects requiring environmental impact assessments.
- **Financing Risk:** Raising the capital required for infrastructure could entail significant financial risk since the level of interest rates and foreign exchange rates seriously affects total project cost.
- **Public Policy Risk:** The nature of public services provided may not be in accordance with the public's wishes, or the services may be delivered in a way that is deleterious to the public good. This risk cannot be shared and falls directly to the government.

7.10 BORROWING

Municipalities generally use debt financing (borrowing) to finance the part of capital works that are not financed by federal or provincial grants. Their repayment comes from operating revenues such as user fees and property taxes. It is usually beneficial to borrow when the benefits from the infrastructure projects are spread over a long period of time. Table 7.4 lists the advantages and disadvantages of borrowing (210).

Table7.4: Advantages and Disadvantages of Borrowing (210)

Advantages	Disadvantages
• The municipality enjoys immediate benefit from the capital improvement which is not always possible with current revenues. • The cost of capital is spread over future beneficiaries (municipal tax-payers). • If per capita incomes are rising, the cost to the individual taxpayer will be less burdensome than that from the full payment initially. • Wide fluctuations in expenditures are avoided.	• Interest costs are added to the total cost of the expenditure. • Potential revenues are dedicated to debt repayment and not available for other uses. • Issuing too much debt can impair the credit rating of the municipality and thereby increase the cost of the capital.

7.11 AN INFRASTRUCTURE BANK

The backlog of infrastructure investment and the urgent need to find new sources of financing, suggests the creation of a new financing institution designed to overcome the defects of the present mix of financing arrangements. According to Peterson, this new institution should (188):

- Provide a stable, long-term financing source to offset the instability of both federal aid and the bond market;
- Use its financial sources to institutionalize new capital management and maintenance practices since new investment would be wasteful if the infrastructure facilities are turned back to the same ineffective arrangements that allowed them to deteriorate, once they are in an improved condition;
- Use its financial resources or leverage tc establish long-term user-fee financing of capital assets wherever possible;
- Link capital financing more effectively to capital planning by requiring the recipients to generate their own assessments of capital condition, long-run capital investment and maintenance requirements, and immediate investment priorities; and
- Allow states and local governments flexibility in deciding on the local priorities for catch-up investment, since they cannot be established uniformly at the federal level.

A federal infrastructure bank linked to a series of state/provincial/regional infrastructure banks would meet these requirements. These banks would make below-market interest rate loans for infrastructure repairs and other infrastructure investments. Once the funds are paid back, they would be recycled to other capital projects (188).

Infrastructure banks represent a long-term commitment to dealing with the capital infrastructure crisis since it guarantees permanent attention to its needs. After all, once a bank has been created and professional staff put in place, it is unlikely to disappear. A bank will have to be there for loans to be repaid. A second generation of lending activity can be ensured if the initial legislation establishes a revolving fund, so that loans that are repaid are recycled to new infrastructure users.

An infrastructure bank should make loans to facilities such as a water or sewer system only on the condition that the full-cost pricing will be used by the system for its services. User fees should include amounts needed to sustain a long-term capital repair and replacement strategy. The bank may also want to make a condition of loans that the local governments operate a system of capital assessment and capital budgeting that meets professional standards set by the bank. These conditions will help ensure that the loan can be repaid and that public funds used to subsidize the loan rates will serve their purpose.

It is very important, and also one of the major advantages of having such an institution, that the bank have exert great leverage on the nation's institutional capacity to plan and manage infrastructure facilities. After all, without such an institution keeping an eye on infrastructure maintenance, there is little to be gained from boosting investment in the infrastructure crisis if we cannot ascertain that once this investment is made, ordinary repairs and maintenance will not again be deferred (188).

The State of New Jersey considered the creation of an infrastructure bank to help localities finance sewer systems, water supply, and recycling facilities. It would get start-up capital from the current federal government grants and state bond issues already authorized but not yet obligated. Local governments receiving loans from the bank would have to agree to raise user fees to help finance the repayment of the loan (121).

Within this bank, revolving loan funds were established to which funds were appropriate for a specific infrastructure purpose. Loans could be made to the local governments at interest rates starting at zero. The Bank was also authorized to issue bonds on behalf of communities for that portion of the project costs not covered by a loan, and could pool borrowing by localities to ease market access. In addition, the Bank could issue revenue bonds secured by dedicated revenues for state infrastructure purposes. A board of directors had the responsibility for the functioning of the Bank and for establishing credit policy. It defined a set of security mechanisms to guarantee repayment of bank loans and bonds, including the intercept of the state aid (61).

Now if an infrastructure bank can work at the state level, then why not at the federal level? Henton and Waldhorn pointed out that a proposal has been developed for a national public works bank into which the federal government would put $1 billion and the states $1 billion. The federal government would use the $2 billion to borrow $20 billion that states could lend to their localities for infrastructure projects. If the federal government were to subsidize 25% of local debt repayments, it would not compete with the bond market and encourage people to go into the tax-except state and the local bond market (121).

7.12 CRITERIA FOR EVALUATING FINANCING TECHNIQUES

Public officials should set criteria for evaluating the different financing techniques. Since not all criteria can be met due to conflicts, at times, it may be necessary to emphasize some criteria more than the others. Slack lists the following principles of public finance to be considered when evaluating different financing techniques (210):

- **Equity:** Equity requires fairness to be applied in the choice of the financing technique. There are two principles of fairness: First, the ability-to-pay principle dictates that people should pay for infrastructure based upon their ability measured by their income or wealth. The second, benefits-received principle, dictates that people should pay according to the benefits they receive from the service, with people receiving similar services paying similar taxes or fees.

- **Economic Efficiency:** An efficient financing technique does not cause organizations or individuals to alter their economic decisions from what they initially would have been before the tax or fee was imposed. There are cases, however, where it is beneficial to alter behavior through taxation or fees, as in the case of the garbage generation.

- **Accountability:** The service provider needs to be accountable to those who are paying for the service. Accountability can be assured through simple, understandable financing instruments that also facilitate compliance.

- **Administrative** The financing technique should not be too costly or complicated

Cost: to administer to the government, to the private sector and to the infrastructure users.

7.13 SUMMARY

The different levels of government do not have the financial means of upgrading or maintaining the infrastructure to an acceptable level. Significant cutbacks in transfers from the federal and state/provincial governments have put a great burden on the local governments. The cutbacks combined with the rising demand for infrastructure renewal, have forced municipalities to seek new and innovative ways to finance infrastructure. Their challenge is to ensure that infrastructure needs are met in the least costly way and to find resources to pay for it. Besides municipal taxes, alternative methods of financing infrastructure renewal are available and some are already being practiced by several municipalities.

However, those making the decisions about financing do not often have enough information on the advantages and disadvantages of the various alternatives, which have been tried successfully elsewhere. Also, the impact of trying something new needs to be considered. Municipal officials and others responsible for financing infrastructure must educate themselves on the different financing techniques available and they must apply them. In addition, public official should try to steer away from financing new projects, unless they are totally necessary. Their focus should be on infrastructure renewal, and not infrastructure development.

Canada should also look into creating an Infrastructure Bank for infrastructure financing. It is a good idea that seems to be working in the US at both the state and the federal level. This would be far more efficient in the long term than the Federal Infrastructure Works Program in Canada.

At a time when budgets are shrinking, the only way that public officials can continue to provide many necessary services, is by turning to the private sector. Governments should also look into tapping the corporate profits in industries such as the banks. After all, infrastructure benefits them too. In addition, privatization is one viable option which could drastically change the way infrastructure services are provided. The infrastructure needs are massive. How will we fund these needs? Privatization may be the best answer to our infrastructure crisis, in our current economic condition.

The role of governments in infrastructure is essential, but it is now time to redefine this role from that of a developer and provider to that of a manager and overseer. Governments should realize that privatization, if properly managed, can result in the provision of efficient and cost-effective services.

However, many functions of the government should not be turned over to the private sector. Public officials must try to steer away from total privatization of the infrastructure and to pass their responsibility on to the private sector. Total privatization may not be good for the society, since unlike the public officials, the private sector is not answerable to the society. The government should have some role in providing infrastructure to the community.

It should be noted that any form of privatization will face public opposition. Society will continue to expect the government to provide traditional services and resist any change in this area. In addition, privatization will also be seen as a threat to the public employees who will fear the loss of their jobs. Times are changing, and society must change with it. However, engineers must be aware of the social implications of the required changes and ensure that the loss of jobs are kept to a minimum. Civil engineers will have to play an important role in educating the public and the public officials about privatization, and its role in providing efficient and good quality services. They should make it clear to the public that privatization will not result in the elimination of services.

8.0 THE ECONOMIC AND SOCIAL ASPECTS OF INFRASTRUCTURE AND SUSTAINABLE DEVELOPMENT

8.1 INTRODUCTION

Most municipal infrastructure facilities have deteriorated to such an extent that they pose a safety hazard and require immediate repair. However, this is not the only reason for repair. Municipal infrastructure is essential for the economic well-being of a country as it ensures the efficient functioning of its production and distribution systems. The existing literature suggests strongly that public spending on infrastructure generates growth in the private sector. Infrastructure renewal is necessary for maintaining and enhancing prosperity. The global economy makes infrastructure renewal necessary, if Canada is to compete in the international markets, since more than any other industrialized country, Canada depends on international trade for economic growth and prosperity.

Infrastructure is a public asset often taken for granted, yet it is an asset we cannot afford to lose. According to Muschamp (New York Times 1994), infrastructure stands for the connective tissue that knits people, places, social institutions and the natural environment into coherent urban relationships. It is the safety net of our social system. When the public infrastructure of a city fails, the entire city as well as our individual daily existence can be dramatically changed.

8.2 INFRASTRUCTURE AND ITS ECONOMIC IMPACT

Throughout the 19th century and for most of the 20th century, infrastructure facilities were considered very valuable for the nation's economic activities and their development was viewed as a nation-building exercise. They were seen as investments that should be expanded, improved or redesigned to enhance the rate of return that could be earned in the private sector. However, as the current investment level in infrastructure demonstrates, this linkage between infrastructure and economic activity has been lost. It turns out that economic development planning and capital planning went on to separate tracks with their own professional orientation.

Today, economic development is guided by short-term opportunities and problems that business demands create due to expansion of active business organizations, relocation, new business start-up, or closing or transfer of some businesses. However, capital improvement programming has a much longer time frame of at least five or more years. Due to this long period of time, it is difficult for capital improvement programs to foresee specific economic development needs and opportunities. This has also resulted in a different kind of system for managing infrastructure facilities since there is a lack of orientation toward economic development. The present decisions about the maintenance, repair and replacement of existing facilities are made as if they are solely public works decisions. They do not take the entire picture into consideration. This situation has left many nations poorly equipped to make reinvestment decisions about infrastructure facilities. Public works officials should give more attention to the potential return on different infrastructure investments such as jobs and national productivity and understand the consequences of public investment and disinvestment (18).

In Canada, as in most developed nations, the proportion of government funding devoted to municipal infrastructure has declined over the last 30 years. Unfortunately, the costs to upgrade and maintain our existing facilities has been rising. As a result, a significant gap has developed between the actual expenditures on the infrastructure and what is needed to maintain it at an acceptable level. In its 1984 study, the FCM estimated this gap to be 25% of the annual investment in urban infrastructure.

It is the belief of many that unless this gap is eliminated quickly, it may grow too large and have a negative impact on the economy. Unless the infrastructure is maintained properly, the efficiency and productivity of the economy may suffer along with our standard of living.

In economics, there are two types of infrastructure investments (196):

- **Economic Overhead Investment (EOI):** This type of investment is oriented toward the direct support of productive activities or toward the movement of economic goods. It includes most of municipal infrastructure such as roads, highways, bridges, water treatment and distribution systems, sewers, airports, mass transit, fire and police stations.
- **Social Overhead Investment (SOI):** This type of investment is aimed at enhancing productivity and quality of human capital. It invests into education, health facilities, and social welfare.

The basic characteristics of infrastructure in economic terms are (196):

- Public infrastructure is the basic foundation of economic activity;
- It generates social benefits or spillovers that exceed what an individual is willing to pay for the services or benefits rather than go without them; and

- The benefits of these facilities are not limited to a group or groups of people and are open to all members of society.

The following quote by US National Council on Public Works Improvements, sums up the importance of infrastructure in the economic well-being of a nation;

"*The quality of life is a crucial index of economic vitality. Reliable transportation, clear water, and safe deposit of wastes are basic elements of a civilized society and a productive economy. Their absence or failure introduces a major obstacle to growth and competitiveness.*" (196)

8.2.1 Public Investment and the National Economy

The Production-Function Approach

The production-function approach is aimed at studying the contribution of public investment to the economy. Of the four approaches available, it provides the most comprehensive assessment of the contribution of public investment to economic growth. Most studies follow this approach and they provide a statistical estimate of a production function, showing the relationship between various inputs such as labor, private capital and public capital, needed to produce a specific level of output.

The basic idea underlying this approach is that public infrastructure is an essential input in the production process. It may increase the firm's productivity in two ways (196):

- By increasing the levels of efficiency of private input such as labor and private capital, employed by an organization. In this case, an increase in the level of public infrastructure will result in an increased output of all organizations in the industry because they all share the benefits of a public infrastructure which are at no cost to them.
- Secondly through its own direct contribution to production as separate input. In this case, the infrastructure as input does not increase the productivity of the private input but contributes independently to the output of the organization.

Empirical Findings (196)

- **Eberts (1986):** This study provides estimates of the direct impact of the public infrastructure on manufacturing output and the technical relationship between the public capital and other production inputs. It found that public capital stock (public infrastructure) makes a positive contribution to the manufacturing output.

- **Aschauer (1989a and 1991b):** This study estimated that increases in GNP resulting from increased public infrastructure expenditures would be higher than those from private investment. In other words, a shift from the private to the public investment would increase the GNP significantly.

Other studies have indicated that an increase in public investment would first depress private investment and as the rate of return on the private capital increases with higher public investment, expenditures on private plant and equipment will be stimulated.

Several production function studies show that public capital plays a direct role in promoting productivity in the private sector by influencing the marginal productivity of private factors of production such as labor and capital. They also show that the decline in investment in public infrastructure by several countries during the 1970s and 1980s, led to a slowdown in the productivity.

Appraisal of Production-Function Studies

Studies that followed this approach generally concluded that there is a positive link between the public infrastructure investment and the productivity growth. However, these studies have various faults (196):

- Their results are not stable since a small change in the data or statistical techniques used can produce large changes in the estimated productivity of the public capital;
- Since statistical analysis captures the correlation between private output and public capital stock, the correlation may be coincidental and spurious, rendering the results ambiguous; and
- Their results lack collaborating evidence. Nearly all of these studies find that private output is influenced more by investment in private capital than investment in public capital.

The Benefit-Cost Approach

This approach has been used by many studies to evaluate the public investment by comparing costs and benefits of individual projects, or a class of projects. It estimates how much of the economic and other costs can be avoided by reinvesting in decaying infrastructure. The studies measured the economic benefits of the project such as increased production of marketable goods and services. This approach provides an estimate of new projects on the aggregate welfare as well as the GNP and also provides a more thorough approach to project investment.

Problems arise using this approach when dealing with aging infrastructure since the knowledge on the rate of infrastructure decay and service life is limited, which makes it difficult to pinpoint when one should reinvest in infrastructure facilities.

Economic Consequence Studies

This approach is similar to benefit-cost approach but deals only with the economic costs imposed by the gradual disinvestment in old infrastructure. It deals with a particular infrastructure facility in a particular area that already exists and fails abruptly or decays slowly or faces capacity constraints to meet the increasing demand. The main conclusion drawn by the studies following this approach is that the benefits of reinvestment in infrastructure exceed the costs.

8.2.2 Infrastructure and International Competitiveness

Before proceeding further, it is important to fully understand the definition of competitiveness. A discussion paper of the Government of Canada, "Prosperity Through Competitiveness", defined competitiveness at the national level as (196):

> *"Creating an economy and a society able to sell goods and services in the world market in such a way that business makes a profit, pays fair wages, provides secure jobs and good working conditions, and respects environments."*

The three level of competitiveness are (196):

- **Organization Level:** At this level, it signifies that the organization can produce and sell goods and services in domestic and international markets on a sustainable basis. Sufficient profits are earned to provide return to investors comparable to returns available from other enterprises and/or countries.
- **Industry Level:** At the industry level, it means sustained viability with returns to capital and labor comparable to those of other industries.
- **Regional Level:** In this instance, it again seeks sustained viability with returns

to the factors of production to keep them in the region.

- **National Level:** Here, it implies a growing standard of living along with a viable balance of payments.

Long term viability of competitiveness at the national level is linked to the following factors (196):

- Productivity;
- Relative costs;
- Comparative advantages and international trade flows; and
- Industrial innovations.

The impact of public infrastructure on competitiveness follows the following logic (294):

> *"Given the exchange rate, the public infrastructure, through its direct (and indirect positive effects on productivity...), leads to lower unit costs. Lower production costs stimulate international trade (especially exports) which in turn is linked to productivity and industrial innovations. For example, an improvement in transport infrastructure will lead to savings in time and lower cost per unit of production output. This in turn will encourage trade between different regions and countries and enhance productivity growth. The search for better ways to upgrade the transport infrastructure will lead to new industrial innovations providing a further boost to productivity growth."*

8.2.3 Infrastructure and Economic Development

The definition of economic development depends on the following two objectives (155):

- If increased employment in a particular region is valued, regardless of the economic costs of achieving it, then an infrastructure investment to foster employment in the region can be considered a catalyst of economic development; and
- If better living standards are required, then the impacts of alternative employment generating policies on economic welfare have to be taken into account before finalizing a plan to promote economic development.

The connection between economic development and infrastructure is based on the following observations (104):

- The development of the basic transportation system enables previously inaccessible areas to offer competitively priced transportation access to goods and supply markets to the private industry;
- Water and sewer systems are needed to complement the transportation network; and
- Residential construction triggers the need for additional infrastructure in the form of educational, health and recreational facilities.

Some studies have found that infrastructure facilities play an important role in the location of new economic activity and make the existing one more viable. One major study citing this link is the report by Biehl and his associates for the Commission of the European Community in 1982. It came up with the following conclusions (196):

- Regional inequalities occur due to the absence and presence of infrastructure facilities;
- There is a positive link between regional development and a region's endowment with infrastructure:
- The contribution of infrastructure to regional development decreases if other factors such as the location are taken into account; and
- Infrastructure endowment is a better explanation of regional income productivity growth than the employment factor.

Infrastructure can affect the decision of firms and individuals on their choice of location in the following ways (196):

- Infrastructure can enhance the amenities of an area or region, thus making it more attractive for firms and households to locate themselves there. These amenities can include infrastructure facilities such as a transit system, an efficient highway system and other recreational facilities.
- In certain areas, infrastructure can lead to an increase in productivity of labor and capital. For instance, improvement of the transportation system leads to a reduction of travel time or cost, and therefore to an improvement of accessibility of markets or imports.
- Investment in infrastructure can lead to a distributive effect which relates to the redistribution of economic activity among regions, while keeping the national total constant, and also leads to generative effects which occur when the national total changes.

Infrastructure affects interregional trade when there is link between infrastructure and transport costs, between transport costs and trade flows, and between trade flows and regional development.

For instance, in a situation with three regions, A, B and C, an improved infrastructure between regions A and B will lead to a decrease in cost for all goods traded between them. In other words, the sum of the trade share of A and B together will increase as a consequence of the improvement of infrastructure in these regions. However, the trade share of region C will be negatively affected.

The maximum and immediate impact on the economy by infrastructure is felt at the local or the metropolitan level. It is at this level that infrastructure facilities can influence the decisions of both local businesses and households.

While infrastructure can have a significant affect on the distribution of economic resources and the rate of economic growth, the effectiveness of infrastructure in promoting change varies according to the industry, stage of production and the infrastructure-intensity of the firm or industry. In addition, the type of infrastructure also has a major impact since newer facilities yield a higher rate of return than the maintenance of existing facilities, or even an addition of new facilities to the existing stock.

Economic growth can be classified into the following (155):

- **Growth in Economic Output:**
  - This is increased total production valued at market prices (e.g. GNP). The two principal sources of output growth are:
    - Growth in productivity which is growth in the production of goods and services per labor-hour worked; and
    - Growth in employment which is the number of jobs, or labor-hours worked.
- **Growth in Economic Welfare:**
  - This is increased economic benefits to society that exceed the increased economic costs of achieving them. Welfare includes commodities like safer roads, cleaner air and less congestion.

8.2.4 Infrastructure and Quality of Life

Infrastructure facilities play a significant role in the maintenance and improvement of our standard of living. The standard of living includes goods and services that people buy and whose value is measured by the volume of the gross output, and the broader economic goods such as time savings, safety and reduced pollution, better health, etc. These are items that do not show up in the national accounts but people are willing to pay for them.

Improving the standard of living equates to growth in economic activity and economic welfare since to achieve a higher standard of living, it is necessary to increase the supply of things that people desire such as less congestion, clean air, refrigerators, etc. The value of these things exceed the value of economic resources such as steel, labor, construction materials, etc., used to achieve the increase (18).

Aschauer (1991) traced out a number of linkages between infrastructure and quality of life. For instance, construction or expansion of a highway system will reduce congestion, and therefore support better health due to clean air resulting from less fumes, greater safety due to fewer accidents, recreational facilities due to better access, economic activity due to better accessibility to suburban jobs, and leisure due to more available time (196).

8.2.5 Economic Consequences of Infrastructure Decay

There are large uncertainties as to the economic consequences of infrastructure decay and it seems that these consequences appear to be highly specific to the areas where it occurs, the industries affected by it and the alternative existing facilities. There are three types of inadequacies and costs that can result from gradual investment neglect in existing infrastructure.

System Failure

This is the most extreme and rare case and such a failure can create obstacles for economic growth and development. However, it is important to note that only a single link in a network will be disabled, instead of an entire network. The actual economic impact will depend upon the criticality of the link, an early substitution of the facility can be substituted with other existing facilities and the time required for repair. Bridge collapses and sewer failures are examples of this type of failure (18).

Facility Deterioration

This is a more common event where the infrastructure facility deteriorates slowly and degenerates into a poor condition and performance. Gradual decline is a more aggravating problem since its effects are cumulative and promote the tendency to defer maintenance until one is forced to take immediate action. Examples of gradual decay are leaking water mains rendering the water supply system inefficient, potholes increasing travel time and sewers unable to accommodate additional demands because of infiltration and inflow (18).

Capacity Constraints

In this case, the existing infrastructure is incapable of handling the existing demands imposed by the economic activity (as in the case with highways), or new federal standards rendering an old facility obsolete (as in the case of wastewater facilities). Capacity constraints pose an upper limit upon the amount of growth that can take place in an area (18).

8.3 INFRASTRUCTURE AND SOCIETY

8.3.1 Reasons Behind the Construction of Public Works

Public works provide the physical infrastructure essential to the social and economic development of the civilization around the world. They make human settlements possible and are indispensable to commerce and industry (235).

The first water improvements had little to do with promoting the health and safety of our society, but rather to improve travel in the city and to flush garbage out of the way of commercial and business transport. In addition, controlling the flow of water helped in the suppression of fires (early watermains were all private). Therefore, water systems were viewed, at the time, as part of the economic infrastructure of the city. However, as cities industrialized in the 19th century, people living in urban communities suffered from several deadly disease epidemics due to the accumulation of excrement, putrid provisions, and a polluted water supply. Hence, sewers and high-quality water supply were implemented to build a safer and more sanitary urban environment. Sanitary drainage systems and wastewater treatment plants were then constructed to increase the public health security and well being. This resulted in important networks linking systems of water filtration, sewage treatment, parks beautification and street alignment. These networks transformed public infrastructure into the primary source of health, safety and human convenience (201 & 184).

In the Wealth of Nations, published in 1776, Smith wrote that the functions of the government should be limited to providing for external defense, affording legal protection and undertaking indispensable public works. The government had "the duty of erecting and maintaining certain public works and public institutions, which it can never be for the interest of any individual, or small number of individuals, to react and maintain, because the profit could never repay the expense to any individual...though it may frequently do much more than repay it to a great society" (235).

When first constructed, infrastructure facilities were considered as new technologies transformed into a process or systemic support for our social needs. Thus, 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. In addition, the early colonists relied on harbors to maintain contacts with their homeland. The very first paved streets, constructed of boards, were introduced primarily to accommodate the transport of goods over muddy and lettered streets, and stepping into rotting refuse (184 & 201).

8.3.2 Social Purpose of Infrastructure

Starting form the middle of the 19th century, our society had come to believe that technological and physical innovations could solve health and safety problems of the urban environment. The improvement of the water systems is one of the best examples that could be given to show us the extent to which our society depended on public infrastructure for its survival and prosperity (184 & 201).

In today's society, infrastructure serves both missions of social justice and economic development. Social justice stresses individual freedoms and rights. All humans should have equal access to the same basic services such as food, water, transportation, communication, health care and education. Economic development stresses efficient production, job creation and wealth. These two missions go hand in hand in ensuring our society prosperity and a high quality of life. After all, social justice is integral to a healthy stable economy, and without a flourishing economy, no society would be able to enjoy a high standard of living (201).

Many public works projects aim at lessening the incidence of disease. The link between public works and public health probes the kind of relationship which is common knowledge but rarely explored in the depth required to add understanding. Public works play a fundamental role in reducing death tolls and disease. They also promote the growth of a burgeoning city and the need to change priorities over time and not be sucked in the attitudes of urban youth when the heady years of expansion are over.

Water, air, and land are essential to the maintenance of life, to food production, and to the manufacture of most natural things. Man's existence, his future advancement and the quality of life he leads depend on these basic resources being available in adequate quantities and the right quality at the right time and place. Pollution, by destroying and grossly contaminating these and other resources, by affecting our health, interfering with species on which we are dependent, or otherwise disturbing the ecological balance, can jeopardize our future existence and well being.

Modern purification techniques can produce effluents of any desired degree of organic purity, but certain trace elements and complex chemicals are not wholly removed, and if these are ingested, they can gradually accumulate and cause long term damage.

Gross pollution of a city's water supply can have considerable effects. Contaminated or inadequate water supplies mean lost man-hours and lost production, and the real cost of such factors could well offset a significant part of the cost of providing proper supplies.

Slums, poorly designed work places, and neighborhoods, without any amenity or recreational facility cause mental and physical illness, and are also the breeding grounds of delinquency and discontent, which can easily undermine civilized existence. A better planned urban environment, and better equipped basic services and with constructive outlets for the population, will become increasingly essential in the years to come, especially when leisure hours grow. As most physical pollution of natural resources such as sewage, originates in buildings, a better urban environment would also help reduce external pollution thus stressing the interdependence of the internal and external environments (201).

Infrastructure plays many roles in our society such as:

- Gives all citizens equal access to clean water for drinking and for a variety of other uses. As fewer people suffer from water-borne diseases, health care costs decline;
- Provides us with adequate and safe sewage disposal systems which protect our environment, health and promote water efficiency by preventing water leakage (304). Proper water and sewer systems also help expand urban areas;
- Provides us with accessible transportation through roads, highways, ports, bridges, and airports, giving society higher capital and labor mobility. This changes where we work and live. People are not confined to congested neighborhoods or in other peripheral places of employment. An efficient transportation system is important for the delivery of goods and services, thus encouraging communications, trades, partnerships and tourism between the various communities and nations. However, traffic volume and congestion contribute to the decline of air quality and loss of time and productivity;
- Creates short and long term jobs and spurs growth when money is invested to either build or repair facilities. This enhances our competitiveness and reduces the rate of poverty in the nation. Hundreds of billions of dollars are lost each year due to the

unused productive capacity of unemployed people. Another hundred billion dollars is lost due to welfare, unemployment and loss of tax revenues. Therefore, investing in infrastructure puts people to work, who then pay taxes and increase their own economic well-being. Finally job creation also attracts foreign investments which further enhances the economic prosperity of our society (53);

- Provides us with reliable power and energy to heat our homes, ensure a reliable telecommunications systems, etc.;
- Hospitals and medical clinics are implemented everywhere to provide an adequate health care system to all communities, rich and poor, assuring the society a healthier and more productive life;
- Building recreational facilities such as parks, sports stadiums, and theaters encourages and allows people to enjoy their free time enjoyably and in a healthy manner; and
- Infrastructure deficiencies raise the marginal costs of producers at all levels of output, which could discourage foreign investors from investing. World Bank studies have found that production costs for goods and services are as much as 30% higher in some cities due to lack of public infrastructure and thus putting the burden on the companies to provide themselves with the required facilities. Recent infrastructure failures in the US were found to cost businesses millions of dollars in lost time and disruption (153).

8.3.3 Urban Sprawl

Urban sprawl is incompatible with the notion of sustainable development and affects society in many ways. This type of development is highly profitable for land speculators and for promoters of housing subdivisions, industrial parks, shopping malls, etc. But at what cost? Their short term profits are made possible by the injection of public funds for building and maintenance, over the long term, for infrastructure and community facilities which may be under-used. In addition, urban sprawl is made feasible by subsidies, grants and tax credits to home buyers and buyers of industrial land on the periphery of the core metropolitan area (33).

This has led to huge investments from the public sector. A lot has been invested in the last twenty years in (33):

- Infrastructure construction and maintenance;

- Indiscriminate subsidies to all types of buildings;
- Converting farm land into industrial parks which, in some cases, are occupied at a rate between 25 and 50 per cent;
- Community facilities serving small population clusters;
- Snow removal from highways and streets; and
- Waste management;

No one really knows the obvious and hidden costs generated by the increased dependence on the automobile caused by urban sprawl, the social costs of thousands of people commuting for two to three hours daily, the costs of maintaining our infrastructure. It is obviously cheaper for the government to provide public services to concentrated populations rather than dispersed ones. In addition, those living in concentrated areas or in or near the inner core, pay taxes that help subsidize those choosing to live further away form the urban centers where, in many cases, they work. Is this fair?

Everyone has the right to have multiple choices in living environments, but society simply does not have the means to pursue a pattern of urbanization fiscally unsuitable and ecologically indefensible. Urban sprawl should therefore be stopped.

8.3.4 Infrastructure's Impact on Society

The planning and implementation of public works projects involves more and more the participation of the community that will in some way be affected by it. This is where the field of social impact assessment comes in. It is more and more crucial that planners incorporate the thought and visions of the society involved or impacted by their projects. Highways will be examined to illustrate some of the social impacts of infrastructure development (92).

Planning Stage

Since land development is associated with highways, land speculation will occur immediately after the residents, neighborhood leaders, developers, business learn that a highway is being considered. Homeowners who feel that the presence of the highway will remove or worsen the attractiveness of their homes will try to sell and relocate, while other residents and landlords will be reluctant to put in improvements and banks will likely be opposed to financing them.

Citizen groups and civic associations may form bringing people closer together in a common purpose which can be gratifying to them. The interests at stake may be so important that some individuals will use as many resources as possible and devote a considerable amount of time to protect or advance the cause. These reactions tend to decrease considerably when the highway department develops equitable solutions to the problem of distribution of cost and benefits of the project. Residents may feel despair, frustration and grief and fear displacement. The longer the highway location decisions takes place, the greater the social and economic costs of not building the highway. This whole process also affects the rapport between the government and the citizens. Trust will either be built up or down with consequences for future citizen to government interactions (92).

Land Acquisition Stage

Land is acquired and the residents are displaced from the highway path. The impact of the experience of displacement is traumatic for some. Relocatees generally suffer socially and psychologically due to the disruption of close and meaningful social ties and the severance from familiar surroundings and services. These consequences can be minimized if they relocate in the same neighborhood.

Businesses and services are also affected by replacement. Some of them may be marginal organizations dependent on their long term clientele from the area, and not survive the relocation. Some may choose to liquidate rather than relocate. Others may relocate and suffer the short term economic losses. The following obstacles are often not compensated by the highway agency:

- Time to develop new customers;
- Ease cash flow;
- Adjust to new layout;
- Smooth disrupted schedules; and
- Counteract high turnover because workers will not commute the extra distance.

Residents who choose to stay may be affected by disrupted friendships, businesses and services, and loss of customers and constituents. Most relationships can be continued at greater inconvenience and travel costs. The same applies if people's place of employment is relocated.

If the highway causes substantial displacement, the housing market tightens in the area and prices increase. In some cases, psychological problems due to overcrowding may result. If the acquired structures are not demolished quickly, they are likely to be vandalized, and the property is likely to become overgrown and unkept. Thus the highway corridor may become unsightly to the neighborhood and depress real estate values. Although highways increase real estate values in the long run due to increased accessibility, it should be assumed that that long term gains will overrun short term losses. As a matter of fact, some residents may move before the positive impacts are realized.

Some of the other possible impacts include possible pressure for rezoning: more rapid development of the area, loss of park lands, woods, countryside, and historical sites, and possible changes in the character of the neighborhood and community (92).

Construction Stage

Some of the benefits are construction jobs and businesses created due to the project. However, most will experience inconveniences created by detours, disrupted traffic, congestion, lost business, dust noise, truck traffic, safety hazard, and hindered emergency services. Vibrations may also damage nearby structures (92).

Post Construction Stage

The positive impacts are realized when the highway is opened to traffic. The highway decreases travel time, gas consumption, accidents, and inconveniences to users. It also increases accessibility to residents, businesses, services, and facilities in the area.

Negative impacts include increased noise and air pollution. To counter these effects, it may be necessary to install soundproofing, insulation, air conditioning, fencing shrubs and landscaping. In addition, spending on house cleaning, painting and maintenance is likely to increase.

Changed land use and zoning may increase density. Combined with increased accessibility, this will contribute to more crowded roads, shops, parks, services and parking. It may also cause competition for local jobs and facilities. Crime and vandalism may also increase. Integration of various new communities in the new multi-dwelling units may generate friction and unemployment. Functional problems for the handicapped and the pedestrians may also result form the compromised access generated by the presence of the highway (92).

Displacement and Relocation

Some of the effects of relocation are:

- Psychological stress;
- Disruption of social ties and established social patterns;
- Loss of time, energy and money devoted to finding new housing;
- Changes in accessibility to jobs, services, and activities; and
- Changes in the economic situation.

In most cases, relocatees are properly compensated by the agency responsible for their expropriation. They tend to move into better housing and many renters become homeowners. Commuting distances may increase somewhat but the most negative changes are the psychological cost of moving and the disruption of social patterns (92).

Community Relocation

In the case where a whole community has to relocate, two critically important features emerge. At first, the quality of the community leadership affects both the economic and social outcomes of relocation. Good leaders generate economic resources and effect savings by anticipatory actions. They also facilitate community cohesion and morale. Secondly, long delays cause frustration, especially when the relocated community has to wait a long time for roads and infrastructure (92).

Boom Towns

Boom towns arise when large construction projects or resource developments occur in sparsely populated areas. They are a result of a major type of new economic activity such as mining and resources development, rural industrialization, military installation, power plants, dams, tourism, recreation or retirement housing. Their consequences are (92):

- Population growth;
- Supply/demand problems for public services;
- Additional tax burdens;
- Friction between the existing and new residents due to psychological and social problems;
- Intergroup conflicts due to conflicting life styles, economic interests, political philosophies and moral values;
- Local institution facing problems due to planning, zoning, negotiations, devising tax schemes and providing new services;
- Large school enrollments and fiscal problems increase the crime rate; and
- Unemployment.

Noise Impacts

Noise has become an important social problems affecting the quality of life for many people. It is a by-product of all large construction projects, traffic, and probably a by-product of the use of infrastructure facilities. It has a negative social impact due to its effect on sleep, speech and communication. It also makes residential areas non-attractive and thus reducing their real estate value. Some measure that may be used to compensate for the inconveniences of noise are (92):

- Operational restriction such as noise standards, operations controls, area restrictions and permits;
- Land use restrictions such as barriers, building insulation, compensation, population relocation, planning, zoning, and building codes;
- Tax measures such as tax incentives and penalties;
- New product regulations such as noise standards and labeling;
- Equipment standards such as maintenance and retrofit; and
- Other mechanisms such as education and complaint mechanisms.

Unemployment

Job displacement may result in depletion of financial resources and reduced contact with kin or friends because the worker cannot reciprocate his social obligations. There may be temporary or permanent loss of social relationships in the work situation that have provided affective support and function aid. There may also be loss of contact with one of the primary social institutions, the union, through which the worker gains a sense of competence or influence in the control of his environment. Erosion of a socially useful role that has given the individual a sense of social identity and the redistribution of wage-earning responsibilities with the family may result in drastic readjustment of the role expectation and behavior of the family members (92).

Infrastructure facilities in terms of "core" infrastructure such as water treatment/distribution and transportation facilities increase the economic activity in municipal areas. New infrastructure construction, as well as maintenance or rehabilitation of existing infrastructure creates a multitude of employment opportunities. Similarly, public works programs increase the level of employment in the community. These programs spark industry in the area of development, such as the construction industry, which leads to progress through possible new technologies and innovations, thereby drastically increasing the opportunities for employment (147).

8.4 SUSTAINABLE DEVELOPMENT AND SOCIETY

8.4.1 Social Aspects of Sustainable Development

Infrastructure facilities play a major role in urban development and therefore, have a major impact on our environment. After all, human settlements are one of the most highly impacting forms of human activity on the environment contributing to air and water pollution, increase in wastewater discharges, soil contamination, depletion of natural resources, just to name a few. Sustainable development of infrastructure requires, among other things, the expansion of water treatment facilities to deal with both the nature of water contamination problems and the environmental by-products of the water treatment process. It also encourages the expansion and up-grading of sewage treatment facilities, the reduction of carbon dioxide emissions and the depletion of non-renewable resources as transportation fuel, promotion of public transit, etc. This change in behavior results in the reduction of environmental degradation, the earth's "life-support" system being conserved and our ecological integrity being preserved. Finally, by living in a healthier environment, we become healthier ourselves.

Several experts say that sustainable development emphasizes a richer conception of social well-being. It can influence our lives in several ways. Sustainable development tries to achieve a balance between the population and the resources in addition to eradicating poverty, which in turn, will contribute to slowing down the population growth and increasing the standard of living (29).

One of its major effects on society is to transform it into a sustainable society whose primary objective is to plan and develop processes in a manner which would improve the quality of life of its residents socially. This is why a sustainable society always tries to meet the essential needs of its citizens for jobs, food, energy, water and sanitation by giving them equal access to transportation, health care services, education, job opportunities, etc. Finally, a sustainable society does respond to the changing community needs by changing its priorities or making new ones and does not simply react to events or circumstances but takes action to prevent threats to a community's well-being (236).

Sustainable development for infrastructure emphasizes a richer conception of social well-being requiring a focus on the quality of development rather than on the quantity of economic growth. It revives growth and changes its quality. It unsolves conflicts between economics and environment in the decision making process. It ensures efficient use of resources and equitable distributions of costs, benefits and services to the community. Its application in a given society results in the reduction of the present environmental impacts to the point where everyone in the society could enjoy a comparable standard of living without substantially increasing environmental degradation. Society shares all measures to achieve this goal and share the results. Implementing its concepts ensures our society a reduction of its level of poverty, an economic progress, an improvement of environmental protection and the conservation of our resources. It also prioritizes basic education, preventive health and the creating of jobs, especially for the lower income segments of the population.

8.4.2 Benefits of Sustainability

Sustainability is good from the social, economic, and environmental perspectives. It can resolve successfully many key issues faced by communities today. Within the context of infrastructure, sustainable development is especially effective. For example, a park can be a sustainable component of the ecology and a community focal point when it is planned not as a parcel but as a system supportive of and accessible to all kinds of living things. It can be (236):

- A catch basin for stormwater runoff;
- A means to mitigate flooding and pollution;
- A centerpiece for economic development initiatives;
- A place of serene beauty and contemplation; and
- A showcase and habitat for local plant and animal species.

Across North America, sustainable development has offered practical solutions to common problems such as the following:

- Seattle based its highly effective recycling and waste reduction program on sustainable themes and now applies the concept in its efforts to curb sprawl, to preserve the landscape of the Cascade foothills, and to enlarge the public role in the planning process.
- Boulder, Colorado, created urban growth boundaries and improved transportation options to sustain its quality of life and scenic edge.
- Austin, Texas, established a Green Builder Program to encourage the use of energy-conserving building practices.
- Portland, Oregon, launched an initiative for carbon dioxide reduction based on sustainable changes to the built environment.
- Valmeyer, Illinois, used sustainable planning practices to relocate outside the Mississippi floodplain and to mitigate future flood damage.

These communities and others demonstrate the multiple goals of sustainable development. It can:

- Enhance a sense of place;
- Reduce crime;
- Mitigate natural hazards;
- Conserve energy and resources;
- Preserve culture and heritage;
- Improve traffic circulation; and
- Reduce waste.

Sustainable development can also attract more viable economic development as competition among communities for high-quality businesses becomes more intense (236).

8.5 INTERNALIZING ENVIRONMENTAL COSTS

According to Hawken, the single most damaging aspect of the present system is that the expense of destroying the earth is mostly absent from the prices set in the marketplace. Markets are superb at setting prices, but incapable of recognizing costs, since they simply do not reflect the true costs of products and services. The cost to future generations due to global warming, resource depletion, etc. needs to be internalized (119).

The debate over the environment and how the environmental factors should be more fully integrated into the way policy makers make decisions is growing. In their book, *Blueprint for a Green Economy*, Pearce *et al.* argue strongly for bringing environmental matters more centrally within the realms of economics. They advocate a greater use of economic instruments, especially appropriate pricing, to tackle environmental issues, by getting the true value of environmental services reflected in the prices, rather than having them treated as "free goods" (19).

Internalizing environmental costs is one way of trying to represent the real costs of development. This can be achieved through government intervention (157). Green taxes can be applied to a wide variety of resources, processes, and products helping to incorporate environmental factors into the infrastructure costing.

If environmental costs are built explicitly into the prices of goods and services, the responsibility for environmental consequences is put where it belongs, on the user, beneficiary, and the final consumer of natural capital. The immediate goal of an economic instrument is to achieve a given level of environmental protection at the least cost to the society, through simple market mechanisms, or through incentive-disincentive taxes and user fees that encourage positive and measurable results (141).

It is essential that we reflect environmental impacts in the costs resulting from activities for which the civil engineers are responsible, such as groundwater pollution, waste disposal, toxic generation, etc. Society usually absorbs these costs via health impacts and a lowered quality of life. We need to tax the pollution and not the production of facilities. Prices charged for municipal infrastructure such as water and sewage/wastewater infrastructure are too low and do not fully cover the costs of maintenance or replacement. In addition, they do not encourage the efficient use of infrastructure.

8.5.1 Application in Urban Transportation

Urban transportation is much more expensive for the government than necessary. Many of its problems are created because of the large investments and expenditures poured into the automobile system. For the past many decades, a wide variety of subsidies, both public and private, have been devised to support the automobile, a fact not realized by most drivers (228). Subsidies are examples of destructive economic policies. Current subsidy structures often promote the opposite of what is needed for a sustainable energy future. They ignore the costs of depleting resources and polluting the air, among other things. Governments should examine hidden and ouvert subsidies and reform those that penalize conservation and end-use efficiency (157). Most of these subsidies are channeled through development itself, in the form of parking requirements, fees and property dedication to roadway enlargement, etc. The best way to bring balance to the economic incentives in the transportation system is to remove most of them from the auto system (228).

Developing policies to tackle the environmental damage associated with transport is a difficult task. One problem with adopting pollution pricing in the transport field is that it is often seen as inequitable, and fears are often expressed that it will become the prerogative of the wealthy. Subsidies, on the other hand, are favored due to the perception that regulations are somehow fairer than charges (19).

Some elements of transportation costs are taken into account in the charges being borne by those supplying the services and by the users of the services, and not all conventional costs are taken into account due to the various government subsidies. However, other costs, such as the environmental costs, are outside of traditional markets and tend not to be brought within the domain of decisions regarding transport provision and use.

Pricing can have a considerable effect on the behavior of transport users. For instance, changes in the real price of fuel affect motorist's choice of vehicle; in the late 1970s and early 1980s, the rise in the real price of fuel was reflected by an improvement in the average fuel consumption of new vehicles, as consumers chose more fuel efficient models. In recent years, as the cash price of fuel has remained steady and has therefore fallen in real terms, the average fuel consumption of new vehicles has increased (206).

One situation that is ripe for green taxes is road congestion. Congestion involves high costs in fuel, time, and stress. It has been estimated by the World Resources Institute that Americans pay an extra $300 billion per year in expenses directly related to our over-reliance on the automobile. One study estimated that by the year 2005, Americans will waste almost 7 billion hours year sitting in stopped traffic, at a cost of over $75 billion. One can add to that the extra fuel use of 7.3 billion gallons, wear and tear of autos, amounting to $40 billion. Accidents increase in tied-up traffic, adding some $275 billion in the annual medical costs. It is really frightening that these figures do not take into account the effects of smog, acid rain, or personal stress.

Rush-hour commuters on congested highways are participating in a market system that does not fully reflect all of the environmental costs. If tolls were placed on highways to account for these costs, automobile usage would decrease, traffic patterns would change, revenues would increase, and congestion would be reduced (119).

Therefore, the best hope for transportation policy is to make people pay the full costs of their trips, while encouraging technologies and land-use patterns and policies that will reduce those costs. The price that drivers pay for their trips (out-of-pocket expense plus the value of time) is typically less than the true social cost of the trip because they are not required to pay for the inconveniences their trips cause. The low price encourages people to take far too many trips by car (168).

If areas are dense enough, and automobiles are not subsidized, transit services can be economically healthy. The only reason transit needs its current high subsidies, is that the automobile is also very heavily subsidized. Withdrawing automobile subsidies (externalities) over a period of time would assure transit competitiveness and economic self-sufficiency (228).

As a group, drivers fail to cover about 12 percent of the costs they impose on the society, and about 60 per cent of the costs of providing public infrastructure and transportation related services. Forcing drivers to pay for the full cost of travel would undoubtedly have major effects on land use and travel patterns (168).

Integrated land use and transportation planning need to go hand in hand with internalizing environmental costs in the transportation sector. Pricing alone will lead to major public opposition and would backfire. Therefore, pricing needs to be phased in slowly in coordination with alternative improvements such as transit systems, so that the drivers do not feel the pinch right away.

8.6 SUMMARY

Infrastructure affects society as a whole by improving the quality of life, creating an environment that favors industrial effectiveness, eases communication, promotes cleanliness and hygiene and by increasing the standard of living. It is an essential factor in the equation of economic and social benefits.

Infrastructure renewal is crucial for economic development. Businesses will hesitate to locate in areas which face decaying services due to delays in infrastructure repair and rehabilitation. Work on infrastructure renewal generates wealth since good municipal systems are essential for the efficient distribution of goods and materials in any developed nation and are critical for the safeguard of public health and the promotion of tourism. Canada needs to attract new employment opportunities and to improve our standard of living, in order to prosper and compete with the international markets. A deteriorating infrastructure threatens our national productivity and international competitiveness, limits our ability to respond to environmental issues and affects our quality of life. The global economy makes infrastructure renewal necessary, if Canada is to compete in the international markets. This can only be achieved with a sound and efficient infrastructure system.

Although the responsibility of sustainable development and infrastructure renewal rests on the shoulders of the three orders of government, they are not, however, the only responsible ones. Each of us, as individuals or business owners, educators, etc. should carry some of the responsibility. We could promote infrastructure renewal and its sustainable development by educating, recycling, reusing, reducing waste, funding research, etc. As a society, we need to go beyond the boundaries of our society and think about the consequences of our acts on the global environment.

One of the main principles of sustainable development is full cost accounting which incorporates all economic, social and environmental costs into the price of a good or service. If implemented, this could have a significant effect on current prices. It could increase the price of most energy types, although some prices such as those of coal and petroleum would increase more steeply compared to hydro-generated electric power. This should encourage consumers to move towards more environmentally friendly sources, resulting in sustainable development. Incorporating environmental costs would also encourage research and development in alternative sources of energy and services (91).

The world population will almost certainly see a substantial increase in growth rate by the end of the century. This growth rate may nearly equal to that of the past 10,000 years over the next 30 years. The provision of food, water, land, housing, infrastructure, etc., for these people will place tremendous pressure on the natural environment even without any advance in the living standards. Urbanization and increased land use place a greater stress on the demand for these basic elements. After all, town dwellings increase the demand on all basic services and also multiple waste disposal problems (201). Without a proper infrastructure system, our society's progress will decelerate. Our quality of life will diminish.

We must act soon. While the future needs of our society may differ from ours, we are still morally obligated to leave our future generations a heritage that will enable them to enjoy our standard of living, if not a better one.

9.0 THE POLITICAL AND LEGAL ASPECTS OF INFRASTRUCTURE AND SUSTAINABLE DEVELOPMENT

9.1 INTRODUCTION

Public works are usually the responsibility of government agencies. Most public works projects are funded in some part by some form of government, and those that are not, still have some government regulations that apply (135). Unfortunately, governments at all levels are retreating from their developmental role to a more conservative function of maintaining infrastructure facilities at a minimum acceptable level (131).

Today's decision makers fail to recognize the cost benefit of investing in and renewing our deteriorating infrastructure and therefore do not adopt it as a policy, as it was done in the past following the second World War (23). The federal, provincial, and local governments need to realize the potential in integrated transportation and land use planning, for sustainable development, and make the incorporation of sustainability into planning, compulsory for all planners.

9.2 LOCAL GOVERNMENTS - POLITICAL AND LEGAL ISSUES

Local governments have a unique and important role in the construction, reconstruction, and maintenance of the infrastructure systems in North America. They have the responsibility for virtually every type of infrastructure and can accurately relate to local needs.

9.2.1 Key Forces Affecting the Municipal Sector

There are several political/regulatory, economic, social and technological forces affecting local governments. In order to deal with these challenges, the municipal body is in charge of generating and maintaining a code of regulations. These forces are (233):

<u>**Political/Regulatory Forces**</u>

- **Provincial-Municipal Relations:**
  - Decrease in transfer payments;
  - Harmonization of programs and decrease of service overlaps;

- Inter-governmental trade agreements;
- Legislative limitations to change; and
- Need for enabling legislation to allow fees for certain services.

- **Expectations of Government:**
  - Expectations by the public of greater accountability;
  - Conflicting demands for resources;
  - Belief in "right" by citizens to entitlements;
  - Demand for efficiency in government services;
  - Decreased credibility of public sector as service deliverers;
  - Higher service expectations by the populace; and
  - Cultural and social diversity of clients.

- **Public Resistance to Government Spending:**
  - Push for less government;
  - Resistance to new taxes and additional funding;
  - Demand for control of debt and deficits; and
  - Decreasing borrowing capacity.

Economic Forces

- **Trends in the Canadian Economy:**
  - There is a need to stabilize funding;
  - General optimism with respect to future opportunities is evident;
  - Need to strengthen key factors;
  - Shift to a service economy;
  - Declining tax base (property and business taxes);
  - Competition from other cities and provinces for business;
  - Need to identify non-tax revenue sources; and
  - Shortage of skills.

Social/Demographic Forces

- **Push to Preserve the Environment:**
  - Increased emphasis on quality of life issues.
- **Demographic Shifts:**
  - Population growth patterns;
  - Aging population;
  - Provincial migration patterns;
  - Population diversity; and
  - High unemployment in particular groups and areas.

Technological Forces

- Increased receptiveness to the use of technology;
- One-stop stopping and use of kiosks;
- Elimination of remote service delivery;
- Delivery of services via PCs;
- Access versus privacy concerns;
- Eliminating the need for labor;
- Need for higher level of skills in government;
- Consolidation and integration of services; and
- New cost-effective environmental technology.

9.2.2 Planning and Managing Infrastructure

Municipalities are the operating authority for most of Canada's infrastructure. They plan, finance, construct, and operate most of the infrastructure that directly relates to the urban property. Large redevelopments, however, require a partnership between the public and the private sectors. The municipalities fulfill their role by providing the required infrastructure, defined by both the partnership agreement and the subdivision agreement for their development. In addition, they are not as involved in the development of new infrastructure when a new area needs to be developed. In this case, it is usually the land developer who constructs the streets, electrical services, drainage systems, water supply and sewage disposal systems, gutters and curbs, according to the standards set by the municipality.

The regional government is a level of government just above the municipal level, in most parts of Canada. They are the principal infrastructure planning authorities that administer and develop the growth of an urban region through a development plan, which deals with the capital budget required, and with the infrastructure needed to develop new areas or to accommodate the needs arising from sub-regional changes in land use. Although they perform identical activities and get the same provincial support as the municipalities, the scale of their activities is much larger. In terms of infrastructure, regional governments are responsible for regional water and sewage treatment, the network of collection and distribution pipes, arterial roads, major commercial routes, transit facilities, waste disposal and the planning and financial management of these facilities or public works.

In many instances, regional governments create special purpose commissions to administer individual infrastructure elements, such as regional transit commissions and water authorities. As with the case of municipal governments, the regional governments get some of their financing through taxes on land development projects. These are known as lot levies or acreage charges (31).

To purchase capital equipment for operations such as buses, engines, pumps and road maintenance equipment, municipalities obtain grants, if available, from the provincial governments. The maintenance and plant administration and other staff perform the operating activities under the general supervision of the municipal works or engineering staff (6).

The maintenance, upgrading and replacement of infrastructure requires that local (municipal) management be well performed. It was observed in the FCM survey results that many municipalities were unable to provide data relating to their present needs, past expenditures and activities of their public works departments. Also, a large number of them stated that the required data was not available and would require a great deal of time to collect it. This lack of information just a decade ago suggests that there is a lack of technical strategies, such as continuous inventory and condition assessment, for renewing and maintaining municipal infrastructure (80). There are now managerial processes available to assist the technical managers in managing their infrastructure efficiently with the assistance of a systematic collection and dissemination of information about infrastructure failures rates, cost-effective maintenance procedures and the most optimum upgrading alternatives (31).

9.2.3 Financing Infrastructure

The main responsibility of financing, operating and maintaining infrastructure such as roads, bridges, sidewalks, sewers, water distribution and sewage and water treatment, falls mainly under municipal jurisdiction. To finance these local services municipalities rely on (5):

- Property taxes;
- Provincial grants;
- Debt financing;
- User charges; and
- Other fees.

Property taxes and provincial grants account for approximately 40%-50% of the total municipal revenues, depending on the Province. Reliance on property taxes has been on the rise since the 1980's, as there has been a steady decline in the provincial grants.

The use of debt financing is on the decline since the 1980s due to the level of debt accumulated, rendering this source of financing unaffordable for most municipalities. The "pay-as-you-go" form of financing poses great problems since infrastructure must compete for the scarce resources with the other municipal priorities. This, combined with reduced financial help from the federal and provincial governments, has significantly reduced the amount of funding available for infrastructure maintenance.

The FCM demonstrated in 1985 that municipal public works budgets have been decreasing relative to the total municipal budgets. There was a decrease of 5% from 1968 to 1983. The public works capital component of the total budget decreased by 5% during the same period as well (5).

The shortage in funds available for infrastructure renewal has forced certain municipalities to search for alternative methods of financing. Some of the methods currently in use and available were discussed in Chapter Seven.

9.2.4 Municipalities and Legal Issues

By 1980, New York City had already paid over $20,000,000 in lawsuits stemming from potholes and other street defects (135). The advent of the 1990s has heralded significant changes in the liability of municipalities. Previously, the courts maintained a non-interventionist approach when reviewing municipal actions. However, in the late 1980s, a number of tort decisions imposed liability increasing the level and risk of tortuous exposure of municipalities.

In order to consider municipal liability, it is first necessary to determine the legal status of a municipality. Municipalities, unlike the federal or provincial governments, are not listed in the 1867 British North America Act Constitution Act, but in later legislation. The provincial governments, through legislation, have incorporated various levels of local governments and delegated them various powers, duties and obligations.

Unlike a business corporation, the municipality cannot take any action not authorized by law. However, given the number of powers bestowed upon it, litigation against it for an alleged wrong may arise in numerous areas. A municipality is under duty to perform certain acts and services and will be compelled to carry out its mandate under statute.

Many claims arise out of accidents occurring on municipal roads and highways. In order for the accident victim to seek redress from the municipality, there must be a duty on the municipal defendant to maintain and repair the road or highway and non-repair must have contributed to the accident. The duty of repair in Ontario on a municipality is statutory and is as follows (159):

> *"Every highway and every bridge shall be kept in repair by the corporation the council of which has jurisdiction over it upon which the duty or repairing it is imposed by this Act and, in case of default, the corporation, subject to the Negligence Act, is liable for all damages sustained by any person of such default."*

The above cited duty of a municipality to maintain a highway required that any non-repair be the cause of injury before the municipality incurs liability. If the injured person has been contributory negligent, the Negligence Act applies in order to apportion liability. However, it should be noted that with respect to some roads and highways, the jurisdiction may be joint between municipalities or between municipalities and the provincial government.

The method through which courts determine non-repair varies according to the individual circumstances. The burden is therefore on the public authority to prove that non-repair existed notwithstanding the fact that it had an adequate system of inspection and maintenance in place.

In law, this has given rise to two kinds of wrongs. Where the terms of the statute are mandatory, liability may be imposed for what used to be called misfeasance and nonfeasance. In this instance, if the municipality does not do what it has a positive duty to do, it gives rise to an actionable wrong. If the legislation is permissive, no liability is imposed for nonfeasance (the omission or failure to perform an act). If, however, the municipality exercises its direction and decided to perform the act and does it negligently or in such a way as to cause harm to someone else, it will be found liable for the act.

For instance, an appellant was stopped in traffic on the highway to Whistler, because of heavy snowfall. While stopped, a boulder weighing more than one ton fell from the slopes above the highway and crashed down on the appellant's car. He was severely injured and his daughter killed. The respondent was sued on the grounds that it had negligently failed to maintain the highway. The BC Department of Highways set up a system for inspection and remedial work. The practice was to make visual inspections from the highway and then a rock scaling crew would act on their findings and recommendations.

The court refused to review the case since it felt this was a matter of policy, not operations. Unlike the Ontario legislation, the BC statute imposes no statutory duty to maintain the roads. This case signified the distinction between policy and operational decisions of a government. The courts have refused to second guess policy decisions of governments, but have reviewed operational decisions. The difficulty is in the categorization of the nature of the decisions. The Supreme Court of Canada found that once this duty of care was established, it was necessary to determine whether there was any statutory obligation or exemption from the maintenance and secondly, whether the inspection constituted a policy decision, in which case, it would be exempt from liability.

In another case, a building was destroyed by fire and an action was brought in negligence alleging that the town and regional municipality failed to ensure an adequate water supply for the fire to be extinguished. The inadequate supply of water was due to an outdated water system and the local governments knew that there was insufficient water to fight a large fire. The local government was exercising a discretionary power in establishing a fire department and operating and maintaining water works and was under no statutory obligation to establish such services. The town was exercising policy decision in not upgrading its water system and for budgetary reasons, did not follow recommendations to upgrade its water system. Therefore, it could not be held liable for negligence.

It can be argued that once a municipality decided to act, its actions are reviewable. However, its actions can be defensible if they result from a policy decision, such as budget constraints. The rule is generally not invoked to impose liability on a municipality supplying a public serve since the doctrine does not apply if the service is provided under statutory authority and without negligence, and if it can be said that the undertaking is carried on for the general benefit of the community (159).

9.2.5 The Federation of Canadian Municipalities (FCM)

The FCM "is Canada's municipal pipeline of communication, transferring ideas, information and new techniques to communities across the nation through its publications, meetings and conferences." It represents the interests of municipal governments and builds bridges of communication between them and the national political leaders, so that they can better understand the needs of the different municipalities (80).

The 1985 municipal infrastructure report concluded that essential facilities as roads, sidewalks, sewers, water facilities, and bridges were in poor condition and deteriorating rapidly. Roads, bridges and sidewalks were found to be in the greatest need for repair. The costs to repair the existing facilities were judged to be around $12 billion ($20 billion in 1993). Since this was beyond the financing capabilities of the municipalities, FCM called for a five-year cost shared program involving the three orders of governments: Federal, Provincial and Municipal (79 & 80).

A consulting firm (Informetica Ltd.) was commissioned by the FCM to undertake an analysis of the economic effects of the proposed program. The results published in 1985, suggested a total increase in employment over a five-year period of about 285,000 person years (79). The report also concluded that such a program could be used as a "contra-cyclical" instrument to generate employment during times of increasing unemployment. The current program has overachieved significantly on FCM's original job creation forecasts.

In an FCM survey of members in the Fall of 1992, regarding their municipal infrastructure, it was found again that there was a need for repair and that lack of infrastructure renewal had negatively affected business opportunities in several municipalities. In addition, priority in infrastructure repair shifted to sewers from roads, bridges and sidewalks. In addition, 88% of the respondents agreed with the FCM campaign for a tri-partite program to renew municipal infrastructure and said that they would participate and assume the financial responsibility for their share. The FCM's proposed national infrastructure program would be undertaken on an incremental, cost-shared basis with each of the three orders of government bearing one third of the cost each. The FCM suggested that the work be spread over five years (31).

The FCM's study on municipal infrastructure led to some of the following (83):

- The public awareness of the infrastructure problem.
- In 1986, the former leader of the opposition, the Right Honorable John N. Turner, addressing the Annual Conference of the FCM in Hamilton, Ontario, gave his support to the FCM infrastructure program.
- The First and Second Canadian Conferences on Urban Infrastructure, co-sponsored by the FCM in 1987 and 1989, respectively.
- In 1988, FCM launched the "Big Fix" campaign to secure support for a cost-shared program.
- At the Annual Conference of the Ministers of Municipal Affairs of Canada's provincial and territorial governments in 1988, the ministers unanimously adopted a resolution calling on the federal government to help finance the construction and rehabilitation of municipal infrastructure.

- At the 29th Annual Premiers' Conference in 1988, the "Premiers urged the federal government to commit itself to provide significant funding so that the provinces can plan to meet the ongoing challenge of maintaining and extending municipal infrastructure."
- The Liberal Task Force supported the FCM's proposed infrastructure program in 1993.
- Infrastructure renewal was a major issue, brought forward by the Liberals in the last federal election.

In 1996, McGill University prepared a report, with some assistance from FCM, on the State of Municipal Infrastructure in Canada. The report, based on a detailed questionnaire of municipal governments, compares the present state of municipal infrastructure with its condition in 1985 (232).

FCM always maintained that there were five basic principles which mitigated for the federal government recognition of responsibility towards municipal infrastructure. These principles are:

- The need for access to clean water by all Canadians;
- The need for adequate sewage disposal systems which protect our environment and promote water efficiency by preventing water leakage;
- The need for safe roads and bridges especially when cutbacks in other forms of transportation are putting extra stress on existing infrastructure;
- The need for the federal and provincial governments to contribute to the huge initial capital cost to upgrade infrastructure; and
- The need for municipalities to implement user fees for the maintenance of water and sewer systems as well as for resource conservation.

For the past year, FCM has been working toward a program to succeed Canada Infrastructure Works through grassroots efforts and media events. Municipal governments have communicated to Members of Parliament, Cabinet Ministers on the Federal Job Strategy Committee and to the Prime Minister that the program has strengthened local economies, enhanced the environment, and created both assets of lasting value and jobs locally. FCM will (232):

- Continue to pursue an extension to the Canada Infrastructure Works Program based on the six principles put forward by FCM's National Board of Directors;
- Continue to monitor the implementation of the national infrastructure program and intervene as necessary;

- Reaffirm its commitment to the concept of user fees as a mechanism to contribute to the maintenance of municipal infrastructure;
- Continue to monitor the evaluation of the national infrastructure program;
- Continue to work with the Canadian Water and WasteWater Association to promote water efficiency in municipalities;
- Encourage municipalities to develop a water efficiency strategy that includes water rates that reflect the full cost of purification, storage, distribution and sewage treatment; a water audit of their own operations; and
- Pursue federal government recognition that water leakage due to aging municipal infrastructure is not water efficient and that the advanced state of decay and the extent of it, cannot be remedied through proper water pricing and will necessitate technical and financial assistance from all orders of government.

9.2.6 National Association of Counties (NACO)

US Counties are often responsible for the management of resources passed on from the state legislature. They have before them great opportunities and substantial risks in their duties. There are opportunities to be more creative with fewer federal strings attached to categorical and entitlement programs. There are tremendous risks as well with the reduced federal financial commitment in exchange for greater state and local control. Devolution, which is the return of power and responsibility to state and local governments is coming in some form or another, and counties need to be prepared.

In 1935, county officials from all parts of the nation banded together to form the National Association of Counties (NACO). They wanted to have a voice in Washington, DC, and to ensure that the county movement was heard and understood in the White House and the halls of Congress. NACO is the national voice for America's approximately two-thirds of the country's 3,042 county governments. Representing the American people at a grass roots level, member counties share important goals and concerns that impact the quality of life in communities across the nation. The organization's primary objectives are to:

- Act as a liaison with other levels of government;
- Improve public understanding of counties;
- Serve as a national advocate for counties; and

- Provide a resource for counties to help them find innovative methods to meet the challenges they face.

The focus of NACO's legislative priorities may change depending on the outcome of the budget negotiations between Congress and the White House. These priorities require a federal, state and local partnership to accomplish them Enacting these priorities will enhance and protect the social and physical infrastructure of our nation's communities.

Many of NACO's legislative priorities will be driven by block grants and devolution approaches. Congress will also continue to work to reduce federal spending. NACO will shape and monitor legislative proposal shifting power and resources from Washington to state and local governments. These efforts may involve developing and promoting policy and legislation to protect counties from federal and state cost shifts. This includes efforts to compel the federal government to fully fund existing authorizations such as payments instead of taxes (234).

NACO's key legislative priorities related to infrastructure are:

- Intermodal Surface Transportation Efficiency Act: Seek and support adequate funding and a 1997 reauthorization of the Intermodal Surface Transportation Efficiency Act (ISTEA) and oppose the use of transportation funds to balance the federal budget;
- Regulatory Reform Act: Support the enactment of this act to require the federal government to consider the impact of new regulations on state and local governments;
- Tax Exempt Bonds: Seek and support legislation to simplify current tax-exempt bond statutes that restrict the ability of counties to finance roads, jails, hospitals, solid waste projects and other public facilities. Seek and support legislation allowing counties and cities to issue mandated infrastructure facility bonds;
- Airport Improvement Program: Support the reauthorization of this program and work to ensure adequate funding for it; and
- Support telecommunications legislation that protects public rights of way and local zoning authority.

In terms of infrastructure needs, NACO finds that local governments cannot alone handle the infrastructure needs with the available resources. They propose the following recommendations (234):

- County governments have the responsibility for major portions of the nation's infrastructure system and should be involved from the start with the development and implementation of a national policy;
- Rural and urban needs should be taken into account in an equitable manner in the development of national policies and programs;
- Local governments should qualify for public works grants and loans primarily on the basis of their infrastructure needs, but also including unemployment factors;
- The federal government should move to consolidate infrastructure grants and loans programs with the goal of maximizing local government flexibility, decision making, and priority setting;
- The tax exempt status of municipal bonds should not be changed in any aspect of infrastructure financing legislation;
- Local governments matching requirements should be minimized especially for economically depressed areas with a demonstrated inability to pay; and
- Federal seed funds for infrastructure banks should supplement rather than replace existing grant programs.

9.3 PROVINCIAL/STATE GOVERNMENTS - POLITICAL AND LEGAL ISSUES

In the US, the state government has jurisdiction over a large part of the infrastructure network. Once the projects have reached completion, maintenance and rehabilitation of the larger facilities is usually delegated to the state agencies. Canadian provincial governments are responsible for all of the major highways throughout the provinces with some exceptions.

The role of the provincial government in terms of infrastructure is to deliver services and define standards for the delivery of infrastructure services by the municipal and regional governments. They also have major funding programs, detailed standards and professional staff for each category of infrastructure. These services facilitate creation of new facilities, rehabilitation and replacement of existing facilities. Provincial governments also carry out important research and development work related to the various infrastructure problems (31).

Each province has a separate and different system for providing grants and provincial funding ranging from about 2% of the total revenues for water treatment to about 18% for roads. The current funding is not adequate for the maintenance of highways and is constantly decreasing. In Ontario for instance, funding decreased by 18.2% from 1975 to 1983 in 1983 dollars (5).

9.4 THE FEDERAL GOVERNMENT - POLITICAL AND LEGAL ISSUES

9.4.1 Planning, Managing and Financing Infrastructure

In the past, the Canadian federal government used to be a major contributor of financing programs in the area of infrastructure. Today, it provides infrastructure for ports, airports and military installations. Its major financial contributions had been in the area of water supply and sewage disposal infrastructure, transportation, and research and development in these and other related infrastructure. It participates with the other levels of governments in several major infrastructure and city-building projects such as Toronto's Harbor front. Currently, a lot of research on infrastructure is being undertaken or being funded by the federal government (31).

The Canadian federal government has in the past played a major role in the construction and financing of infrastructure. However, contrary to what many may believe, the government's main role was not to provide infrastructure to the general population, but to create jobs. When their concern shifted to the quality of infrastructure, it was done so by focusing on the construction of new facilities rather than maintaining the existing facilities. Federal assistance in the past has been provided as (5):

- **Municipal Improvements Assistance Act (1938-1940):** This program provided loans for water and sewage improvements projects to provide jobs and reduce unemployment.
- **Municipal Development and Loan Act (1963-1966):** This program provided assistance for sewerage and transportation facilities again to create jobs.
- **Special Areas Program (1969):** This program was created by the Department of Regional and Economic Expansion to provide both employment and attract industry to the areas which were designated to receive the assistance.
- **Canada Mortgage and Housing Corporation (CMHC):** In the late 1950s, the CMHC became involved in the development and delivery of federal infrastructure assistance programs.
    - **The Sewage Treatment Program (1961-1974):** This program provided loans, a portion of which were forgivable for the construction of sewage treatment and collection facilities. Its main objective was pollution abatement. During the life of this program, the forgivable portion of these loans amounted to $131 million in grants, while the loans totaled $979 million.

- **Municipal Infrastructure Program (1975-1978):** This was basically an extension of the previous program with an increase in both the range of grants and types of projects made eligible. An additional objective was introduced to encourage land management in undeveloped areas. This way new development was encouraged over infilling of the older developments. Over $1 billion were provided as loans and $395 millions in grants.
- **The Neighborhood Improvement Program (NIP):** This program was initiated in 1973 to provide funding on a cost-sharing basis for improving infrastructure in low-income residential areas. The federal government provided 50% of the costs while the provincial and municipal governments contributed 25% each.
- **Community Services Contribution Program (CSCP) (1979-1980):** This program, enacted under the National Housing Act of 1979, allowed for funds to be to be made available to social and recreational facilities in addition to sewer and water programs. The funding was provided in the form of block grants allocated to the provinces based on a formula taking into account the population and income. The grants handed out as part of this program totaled $221 million.

According to a report released by the House Committee on Public Works and Transportation (renamed the House Committee on Transportation and Infrastructure), US federal spending on infrastructure has been declining. In 1965, infrastructure spending was 6.3% of the federal budget; by 1992, however, only 3.0% of total federal outlays were devoted to infrastructure. This under-investment in the nation's infrastructure threatens our national economy and living standards (235). Examples of facilities financed by the federal government are:

- Airports;
- Harbor facilities; and
- The Trans Canada Highway.

9.4.2 The National Council on Public Works Improvement

The National Council on Public Works Improvement, a joint council appointed by Congress and the US President, outlined a strategy for getting to the root of the problem. Some of its recommendations included a national commitment shared by all levels of government and the private sector to increase capital spending by as much as 100% above the current levels. In addition, the council advocated that Americans:

- Clarify the respective roles of state, local, and federal governments in the design, construction, and management of infrastructure in order to focus responsibility and increase accountability, with civil engineers playing a significant role in this initiative.
- Allow spending of the federal highway, transit, airport, and waterway trust funds so that they may achieve their intended statutory purposes.
- Increase the use of user fees in financing the infrastructure.
- Remove limits on the availability of tax-exempt financing for state and local self-help efforts.
- Support more research and development to accelerate technological innovations and for training public works professionals.
- Develop a rational capital budgeting process at all levels of government.

According to the US Department of Commerce, infrastructure use by industry alone will increase by 30% in the 90s. Therefore, the council report recommends that users and other beneficiaries pay a greater share of the cost of infrastructure services. In addition, while the federal government should remain a reliable partner in financing public works, states must also develop comprehensive infrastructure financing strategies (189).

9.4.3 The Federal Infrastructure Works Program

Canada Infrastructure Works was a federal government program intended to accelerate the economic recovery by creating short-and long-term employment through investment in local communities, while meeting the needs of renewing and enhancing the physical infrastructure in local communities.

When the new federal government took office in 1993, Prime Minister Chretien named the Honorable Art Eggleton as Minister Responsible for Infrastructure. Following the meeting of the First Ministers on December 21, 1993, all ten provinces concluded framework agreements with the federal government.

The purpose of the five year program was to provide a total of $6 billion in investment in order to (30):

- Upgrade the quality of Canada's physical infrastructure in local communities;
- Provide for timely and effective employment creation and skills development;
- Improve national, provincial and local economic competitiveness; and

- Promote improved environmental quality, including the introduction of environmentally sustainable practices and technologies.

Examples of projects funded under the program were:

- Water treatment and distribution systems;
- Sewage and drainage facilities;
- Earthworks;
- Roadworks and related construction activities;
- Refits; and
- Construction of public facilities

The program was a five-year cost-shared initiative. The federal government contributed $2 billion, which was matched by $4 billion from provincial and municipal governments, for a total of $6 billion. The federal share of the funding was allocated to each province and territory- and to Indian reserves in a province- using a formula which gives equal weight to the population share and the unemployment rates. Each of the provinces added their own criteria to the ones specified by the federal government.

The framework agreements specified basic criteria for the projects to be approved for funding under the Program as follows (30):

- Incrementality and/or acceleration of investment;
- Short- and long-term job creation;
- Enhancing Canada's economic competitiveness;
- Use of innovative technologies;
- Bringing infrastructure up to community standards, codes and by-laws;
- Enhancing environmental quality and sustainability;
- Use of sound, innovative financing techniques, which may include private capital; and
- Distribution of program benefits within a province or territory.

According to Soberman's review of the program, allowing for the effects of government borrowing on future debt, the most likely estimate of net job creation over the 1994-2003 period is approximately 81,000 person-years. He cited the following strengths and weaknesses of the program (211):

- **Strengths:**
    - The Program fund were, in the main, spent wisely;
    - The condition of municipal infrastructure was appreciably improved;

- Jobs were created for persons who were largely unemployed;
- Improvements in the economy are comparable to the debt reduction alternative;
- No serious harmful effects on the economy were identified; and
- Contributions were made to the quality of urban life.

- **Weaknesses:**
  - Level of incremental spending. Employment and other economic benefits are directly related to incrementality and except for Quebec, there appears to have been little serious effort to enforce this Program requirement.
  - Approximately 60% of the funding was directed to the construction of new expanded facilities; and
  - There is some concern that capital subsidy programs mask "real" costs, encourage inefficient use of resources, and discourage the introduction of pricing and demand management.

According to the 1995 McGill/FCM Survey, the majority of the respondents found that the federal program funded the most important projects in the municipalities, with 82% in agreement and 12% in disagreement and another 6% being not sure. It was found that the larger municipalities felt that the program allocated funds to the most important projects on a more consistent basis than the smaller municipalities. However, this rate was higher than 57% for the municipalities indicating the success of this program. The majority of respondents felt that they did not share the costs of the programs that were not considered to be the most important. Over 75% of the respondents in each population group agreed that the program funded projects which were considered the most important by their municipality. The overwhelming majority of respondents felt that the program was effective in improving the current status of the Canadian infrastructure.

It is hardly surprising that most municipalities were pleased with this program and declared it a success. After all, they received funding from both the federal and provincial governments, that they would have otherwise not received. In addition, the program had no restrictions on new construction, which gave the municipalities total freedom on diverting the funds to new, visible, and politically advantageous projects. In addition, how could the municipalities be sure about the program actually ameliorating the current state of municipal infrastructure, when most of them are ignorant of its actual condition, as shown by the same survey. Besides, how could a program, which funded more new construction, over renewal, be effective in improving the current state of municipal infrastructure in Canada.

9.5 POLITICS OF INFRASTRUCTURE

Since infrastructure is financed by the government, it is a highly political field, which exaggerates the difficulties of managing the infrastructure. It is also the reason why our infrastructure is in such poor condition. The development, rehabilitation and replacement of infrastructure is not entirely dependent on whether there is an urgent need for it, but on the fact whether it is in the interest of politicians to do anything about it. Urban developers and business organizations will have an interest in the development of infrastructure that is favorable to them, and not to the general society at large. For this reason, they often support political candidates who promise them what they need. This support is usually financial, which is highly unlikely to be turned down by the politicians. This in turn adds to the deterioration of our infrastructure since politicians are normally not out there to basically improve the quality of life in the constituency, but to please their campaign supporters and to get reelected.

Therefore, unless businesses or private developers have a strong interest in the rehabilitation of our infrastructure, we are more likely to see the development of new infrastructure, which is highly visible and politically rewarding, rather than the maintenance of the existing infrastructure, which is not as attractive for reelection purposes.

Another political problem that managers have to deal with is the problem of standards. Contrary to what we may think, engineers do not always determine the best standards. They are not really to blame because the process of setting standards is a political one involving the opinions and interests of both engineers and other related and interest groups. And since these standards are usually based on biased points of view, the result is not a rational set of standards, but a political set instead (106).

9.5.1 Government Priorities

The local electoral system places many demands on public officials (205):

- Meet campaign promises;
- Demonstrate substantive accomplishment;
- Secure some symbols of action and representation; and
- Structure the public investment in infrastructure and its location.

The link between political gain and the development of urban infrastructure is a permanent feature of North American politics. Our cities have largely been shaped by the needs and desires of local officials. Bridges, streets, and sewer lines are not only built because they carry some unique intrinsic value to some city decision maker, but also because of the larger benefits and rewards they promise (205).

Besides elected officials, the political value of infrastructure is also realized by public agencies and their managers seeking to build outside support, enhance their professional image, and enlarge their programs and budgets. Infrastructure programs and projects serve political purposes to urban professionals for rewarding an important or supportive department head, sustaining city employment and employee loyalty, and absorbing and alleviating fiscal pressures and budgetary crises (205).

Politics offers an opportunity to meeting infrastructure needs. As long as elections can be won by resurfacing roads and votes can be gained from rebuilding sewers, infrastructure needs will continue to be addressed.

9.5.2 Regulatory barriers

Federal, state/provincial and local regulations often have a combined negative effect on the development or rehabilitation of infrastructure. There are continuing public management problems with uncoordinated restrictions, redundant laws and regulations, and contradictory requirements.

According to Grant, the Government should establish policies that include life-cycle costing as an element of infrastructure investment analysis. In addition, the government should reduce regulatory barriers to public-works infrastructure development at all levels of government. All orders of government should require all agencies to consolidate, streamline, and integrate their multiple regulatory responsibilities. Finally, a single administrative processing/permitting agency should be established to shorten and improve the approval process of public-works infrastructure projects (105).

9.5.3 Infrastructure for Job Creation

In federal politics, infrastructure is always linked to jobs. It is believed that infrastructure projects create new jobs. Various bills have been introduced into the US Congress on the premise that public works funding will immediately create thousands of new jobs. In 1982, former Secretary of Transportation, Drew Lewis, estimated that the gas tax increase would create 58,000 jobs for every $1 billion spent. Although his estimate was optimistic, the true figure is still not clear (121).

One may assume that infrastructure is the answer to the economic crisis by merely increasing the quantity of infrastructure spending will not put public investment to work in helping revitalize the national economy. Infrastructure spending also has implications as a means of short term economic stimulus. While high rates of return projects cannot be expected to contribute significantly to growth in net new employment, this is not to say that infrastructure investment ought to be dismissed from the list of near term priorities.

9.5.4 Private-Sector Involvement

Increasingly, the politics of infrastructure will move toward non-traditional solutions involving the private sector. Alternatives involving new types of public-private approaches will be increasingly sought to attract both business, which does not want to see an expansion in government spending, and government leaders, who are looking for new ways of doing business with the private sector.

It is important to note that there is great diversity of viewpoints of stakeholders in the private sector. Different businesses have different interests in infrastructure and not all private interests will come to an agreement on the infrastructure issue. An example is the protests of independent truckers against the gas tax. Developers of residential areas may be willing to pay for infrastructure, while "no-growth" residents oppose them. Those interested in health will have different views about water quality standards than rate payers and companies wanting to avoid investing in costly pollution control. Therefore, future political coalitions will depend on the types of infrastructure to create, what the standards will be, and who will pay for the facilities and services (121).

One of the many components of the legislative picture for infrastructure financing is in the area of private sector investment in infrastructure. New Jersey developed two bills aimed at allowing and encouraging private sector investment in wastewater treatment facilities and resource recovery facilities. The latter was designed to subsidize the cost of disposing of waste resources recovery facilities as compared to disposal at landfills. Both bills provided procedures for commutative procurement of private sector services in these areas, but allowing for contract negotiations. The bills provided for long term contracts, and established public rate setting procedures outside the regulated utility umbrella to preserve possible tax benefits (61).

In the Deficit Reduction Act of 1984, Congress established the legitimacy of service contracts between private vendors and resource recovery and wastewater treatment services, and the public sector. Investment tax credits could be claimed where certain reasonable tests were met and service contracts established (91).

9.6 INFRASTRUCTURE AND LEGISLATION

9.6.1 Legislative Trends

Bacon, finds that there seem to be only two sources of additional public funding for infrastructure (14):

- New federal, state or local taxes; and
- Diverting money from current operating program budgets.

Although State and Local legislators are increasingly become aware of the infrastructure crisis, it will still be hard for them to address infrastructure funding legislatively for many reasons outlined by Bacon (14):

- The "tax-revolt" makes the public and lawmakers very unreceptive to new taxes at all orders of government;
- Efforts to cut the federal deficit will focus on domestic "discretionary" spending which supports capital projects in flood control, transit and water quality;
- Federal tax reform will complicate the problem for state and local governments if their taxes are no longer deductible on the federal tax return. As a result, it would be harder to win support for increased taxes;
- Lower federal marginal tax rates will reduce the favorable interest rate advantage of tax exempt municipal budget, driving up local and state borrowing costs for capital projects;
- Federal tax reform will make privatization projects less attractive if the investment tax credit and accelerated depreciation provision of the tax code are reduced or eliminated. State and local governments will be faced with larger financing burdens with the loss of "back door" access to the federal treasury provided by privatization;
- Efforts to reallocate existing revenues towards infrastructure will start from a very low base relative to the need for such funds since capital spending is at a historic low point;
- It will be difficult to shift resources from current operating programs to build and maintain capital facilities within the confines of current revenues. This is illustrated by the difficulties in cutting entitlement programs and defense at the federal level, and this applies at the state and local level too; and

- Public works spending is caught in a stalemate between those who oppose any new taxes and those who oppose any reallocation of budget resources away from the current operating programs.

According to Bacon, we can expect the following actions from state and local legislators (14):

- The increased visibility of infrastructure projects will lead legislators to allocate "windfalls" and other one time surpluses to capital projects. Unfortunately, this is a very short-term solution to a problem requiring long-term actions;
- Efforts will be made to enact marginal improvements to the use of debt financing for public capital projects, such as bond banks, state supported bond pools to cut local borrowing costs. However, these do not address the basic need for a larger cash flow to support capital projects not funded by user fees;
- Local governments will be required to meet matching fund requirements in order to obtain access to limited new sources of capital outlay funds at the state level. However, this use of leverage will help increase total capital spending at the cost of some loss of local control;
- As the infrastructure crises worsens, we can expect the creation of more state level commissions to study the problem and raise the level of public visibility of this issue; and
- The superior taxing and borrowing capabilities of the states over local governments, will gradually lead to reliance on state funding of primarily local capital projects. This may decrease local control of key infrastructure decisions that will shape the location, pattern, and timing of urban growth.

Proposals to leverage public capital resources and to stimulate investment of private capital in public works usually requires federal and state legislation. Some examples of US legislation related to infrastructure are:

- Oregon and Washington have enacted legislation to assist local governments in financing infrastructure;
- In New Jersey and Massachusetts comprehensive legislation was under consideration to establish Infrastructure Banks; and
- New Jersey amended laws to allow private investment in wastewater treatment and resource recovery facilities;

There were numerous bills in Congress to survey infrastructure needs and provide new funding sources, but none have so far been enacted. One proposal in the House was to establish a National Infrastructure Fund to loan money to states to capitalize infrastructure banks. In addition, Senate considered legislation to grant such funds to States (61).

Public officials, in general, recognize the need for legislation to facilitate infrastructure renewal and its financing and have called for regulatory reform which refers to a reduced regulatory burden such as less red tape, increased efficiency, and lower cost of compliance or construction. This would ease the way for infrastructure financing, however, changes in regulatory policy directed at eliminating impediments to investment are also necessary (61).

States and localities must be able to finance their capital needs without undue interference from the federal government. The Congress, governors and mayors, are exploring ways to increase the ability of states and localities to use tax-exempt financing. Through the tax-exemption on municipal bond interest, states and localities are able to leverage minimal federal assistance into substantial capital for investment. This system allows the federal government to encourage public investment without extensive federal involvement (235).

The Rebuild America Coalition endorses the recommendations of the Anthony Commission and supports the following legislative initiatives (235):

- **Ease restrictions on tax-exempt bonds:** The Coalition supports legislation that would ease some of the more onerous restrictions on tax-exempt bonds through increasing the annual issuance limit for the arbitrage rebate exemption from $5 million to $10 million; indexing the statewide private-activity bond volume caps for inflation; increasing the annual issuance limit for bank-qualified tax-exempt bonds from $10 million to $25 million; and clarifying the definition of investment-type property. This legislation would be similar to the Public Finance and Infrastructure Investment Act of 1993 (HR 3630) introduced by Rep. Bill Coyne during the 103rd Congress.
- **Create tax-exempt municipal savings bonds:** The Coalition supports legislation that would modify certain rules applied to tax-exempt bonds structured to be sold as zero-coupon bonds in small denominations to individuals. Such bonds are similar in nature to U.S. Series EE bonds, used by investors to save for things like a first-time home, college education and retirement. By making it easier for issuers to offer new

types of securities designed to meet investors' specific needs, such legislation would provide states and localities with more flexible financing options and greater liquidity for their debt. The new "mini-bonds" would also provide a mechanism through which a broader spectrum of individual investors could participate in the process of improving the infrastructure of their communities.

- **Reform alternative minimum tax treatment on municipal bond interest:** The Coalition supports legislation that would eliminate all taxation of tax-exempt bond interest under the corporate alternative minimum tax (AMT). This would broaden the capacity of corporate entities to invest in public projects, return demand to the municipal securities market, and reduce borrowing costs for states and localities. Since 1986, the AMT has discouraged capital investment by making certain tax-exempt securities less attractive to potential purchasers. Reducing or eliminating the applicability of the AMT to tax-exempt bond interest would return a considerable amount of the demand and liquidity to the tax-exempt bond market that was depressed by 1986 tax reforms. Currently, there is a provision in HR 1215, introduced by Ways and Means committee chairman Bill Archer, that would eliminate the application of the corporate AMT to municipal bond interest after December 31, 1995.
- **Enhance secondary market for infrastructure debt:** The Coalition supports legislation that would create structured instruments on the secondary market by "securitizing" tax-exempt bonds and infrastructure loans. Similar to the secondary market for residential mortgages, the securitization process for infrastructure debt would combine traditional bank lending and the sale of securities to public investors. A secondary market would provide a cost-effective, private sector solution to meeting the infrastructure credit needs of state and local governments and private entities charged with meeting federal and state mandates. Enactment of legislation would free up significant amounts of investment dollars for infrastructure financing and would lower the marginal borrowing costs for state and local issuers.
- **Remove barriers in the tax code to public/private partnerships:** The Coalition supports the creation of a new category of tax-exempt bonds that would be called "Mandated Infrastructure Facility bonds" or "MIF bonds." MIF bonds could be issued by local or state governments to finance the construction or acquisition of an

infrastructure facility that is mandated by the federal government or to pay for that part of an existing infrastructure facility that is required to be renovated or rehabilitated in order to comply with a federal mandate.

Other examples of legislation related to infrastructure include the Clean Water Act was last amended in 1987 and authorizations under those amendments for federal financial assistance for municipal wastewater treatment construction have expired. It has been the US's most successful environmental infrastructure program. Since its inception in 1972, the quality of the water on over 50,000 miles of waterways has improved significantly as a result of the federal government, states and local communities joining together to finance water pollution facilities--sewers and wastewater treatment plants. These capital facilities have also generated substantial economic growth.

Finally, in the 104th Congress, the U.S. House of Representatives has approved legislation (HR 961) to reauthorize the Clean Water Act. This bill includes authorization for the wastewater state revolving loan fund program at $2.25 billion in fiscal year 1996 and $2.30 billion in fiscal years 1997 through 2000. It also relieves municipalities from burdensome study and planning requirements that were carried over from the former construction grants program (235).

9.6.2 Infrastructure Banks

An infrastructure bank can be put into place more easily if state and local governments volunteer to surrender some of their current borrowing capacity in exchange for this new financing vehicle. Federal policy should allow local discretion in deciding how any new infrastructure dollars are spent. Peterson finds that if infrastructure finance is a priority, these governments might consider or be required to consider offsetting reductions in the volume of tax-exempt debt issued to support middle-income housing mortgages or industrial development (188).

New Jersey pioneered the development of innovative financing mechanisms to meet infrastructure financing needs through a Infrastructure Bank. Financial aspects of this proposal were developed over more than a year, beginning in early 1982, and embodied in enabling legislation for consideration by the State Legislature. Although its legislation was designed for New Jersey, Massachusetts also modeled its program after it with minor modifications. The New Jersey Infrastructure Bank legislation was designed to meet four goals (61):

- Leverage public financial resources;
- Provide stable and continuous sources of funds;
- Minimize the local impact of changes in spending patterns or mechanisms; and

- Reduce the State's reliance on the issuance of general obligation debt to meet its infrastructure needs, helping to insure retention of the State's triple-A credit rating.

The legislation established a non-profit financing organization authorized to accept funds from a variety of sources including federal grants, proceeds of state general obligation bonds, state appropriations for the general fund and specific revenues dedicated to the bank (61).

9.7 FUTURE PUBLIC/ GOVERNMENT POLICY FOR INSTRASTRUCTURE AND A SUSTAINABLE FUTURE

For further development to occur in the engineering and construction field, the rate of innovation needs to be accelerated and the current barriers to the innovation process removed. Innovation has a key role in achieving development which is environmentally sustainable. The Government can play a significant role in promoting innovation since the construction industry is too fragmented and individual companies cannot adequately protect their own innovations. The benefits to sustainability are just too great for the government to ignore.

9.7.1 Regional Planning Boards

Currently, land use is predominately a local government issue and transportation is a shared responsibility of federal, provincial/state, and special districts in which local cities and towns usually play a minor role (62). This can create problems when trying to integrate urban transportation and land use planning. The process would be a lot simpler if transportation planning and land use decisions were made by the same body.

The States/Provinces have given local governments powers to control the character of development but have retained control over major highways, the backbone of metropolitan transportation systems, leaving feeder roads and transit systems mostly to local control. This division among state/provincial and local governments has failed to produce rational or systematic strategies for development of metropolitan areas, in which most North Americans reside and work. In order to bridge this governance gap, the federal government must encourage the formation of regional or metropolitan agencies to provide information on growth trends, prepare long-range plans to meet future needs, and support implementation efforts .

Regional organizations exist in almost every metropolitan area to provide forums for coordinating the plans of local governments. Unfortunately, they are seldom effective in curbing the land use excesses of local governments or pursuing coordinated metropolitan growth strategies. They usually just provide data, services, and some planning (190).

Often the decisions of these regional and state/provincial agencies are influenced more by the laws and regulations under which they operate than the local needs. The result is a mismatch between transportation and land use decisions making the results inefficient and environmentally damaging (21).

Most regional plans are only advisory since few regional agencies have the power to coerce local governments to respect regional plans, and regionwide strategies usually vary significantly from plans of individual local governments. Agencies that have the power to require local plans to conform to regional goals, frequently avoid the hard choices since they are financially dependent on their constituent local governments and basically controlled by them. In addition, the jurisdictions of most regional agencies encompass areas that are either too small or too large for effective control of metropolitan growth. Many include wide rural areas that will not be urbanized for several decades, thus diffusing their urban focus.

Regional organizations are able to mobilize support for regionwide strategic planning and action for serious and common issues for all jurisdictions, if they have sufficient powers. Metro, the regional planning agency in Portland, Oregon, is one of the most powerful regional agencies in the US with responsibility for land-use and transportation planning. It has an elected council with legislative power to require local governments to adjust their plans to comply with regionally adopted plans for land use and transportation.

Metropolitan regions are needed to look out for the metropolitan good and to consider the future development of the region as a whole and incorporating the strategies for sustainable development. Such organizations should have the mission and budget to formulate workable regional plans, and powers to influence funding allocations and implementing regulations throughout the region, and overriding decisions made by local councils on critical issues. In general, they should be responsible for determining the conformance of local plans with regional plans and reporting inconsistencies to the local governments (190).

It is important to note that regional municipalities are difficult to implement in some areas, such as the Island of Montreal, because there are simply too many municipalities with different goals and agendas. Most of them should be either merged as was done for Laval or else a more powerful regional municipality should be created. The current system in Montreal is so bad, that the municipalities are having troubles agreeing on a solid waste recycling program, let alone sustainable development.

9.7.2 Sustainable Development Legislation

The increase in political involvement in environmental issues has led to several new laws governing sustainable development and its effects on the environment. Many of them were influenced by public servants working at the municipal level, as well as government officials such as environment ministers. The following are some current federal laws related to sustainable development (52):

- Canadian Environmental Protection Act;
- Clean Air Act;
- Migratory Birds Act;
- Fisheries Act;
- Transportation of Dangerous Goods Act;
- Hazardous Products Act;
- Hazardous Materials Information Review Act;
- Arctic Waters Pollution Prevention Act;
- The Atomic Energy Control Act;
- International Boundary Waters Treaty Act;
- Navigable Waters Protection Act;
- Northern Inland Waters Act; and
- Territorial Lands Act.

Canadian legislation concerning sustainable development usually provides an endorsement of the idea of sustainable development but without details on how it may be achieved. The Canadian government should follow the lead of the Protection of the Environment Administration Act of New South Wales, which attempts to move from the philosophical to the practical by identifying principles in decision making that are consistent with sustainable development.

There appears to be a high degree of agreement about the nature of sustainable development and its intent at a philosophical level. However, there tends to be significantly less agreement, even within the jurisdiction, about it is to be achieved through decision making and actions. This is like having decided on an ultimate destination, but disagreeing on the mode of transportation to use to get there (213).

Sustainable development must be developed further at the policy level for it to be implemented properly. Its inclusion in legislation as a purpose or intent, is not sufficient. The lack of action plans in legislation means that attainment of the goals of sustainable development is improbable. The lack of specific principles to follow or goals to strive for, leaves statutory decision makers uncertain as to what sustainable development requires of them.

We have a long way to go in achieving sustainable development. We must hope that this very popular concept does not become so inflated with good intentions that it will inevitably burst.

A 1990 study conducted by the Canadian Environment Assessment Research Council identified the following barriers to the integration of environmental considerations into federal public policy decision-making (29):

- Lack of clear objective;
- Insufficient political will;
- Tendency of government actors to define issues narrowly according to the prevailing focus of their programs or department;
- Absence of institutional or social incentives;
- Absence of accountability;
- Bureaucratic policies and inertia;
- Lack of information mechanisms to help monitor progress;
- Lack of scientific knowledge about the significance of impacts;
- Lack of economic and other analytical tools to facilitate integrated decision making; and
- Inter-departmental and inter-jurisdiction fragmentation of responsibility.

In general, law reform initiatives help to promote infrastructure sustainable development. The government has to implement laws that prescribe or proscribe certain behavior such as the dumping of recyclable materials like steel beams, to encourage recycling and the reduction of waste generation. They could also ban demolition unless proven unavoidable.

Governments need to pass legislation to help structure decision-making in certain existing practices such as the current contracting and bidding system. Government regulations could require that contracts be awarded based on experience and eligibility of the construction firms rather then on price. Government should incorporate the notions of sustainable design and life cycle costing in the national building code. It needs to establish sustainability criteria for licensing, approval and screening authorities like it was done in the case of the proposed British Columbia Sustainability Act and the Provincial Land Use Strategy.

Recently, the government began to include the promotion of sustainable development explicitly in mandates of departments and all organizations, such as the Manitoba Mines and Minerals Act. Other examples include establishing sustainability criterias for public policy decision-making in the Mandatory Environmental Assessment Policies, Ontario Environment Bill of Rights and the forthcoming amendments to the federal Auditor General Act requiring all departments to promulgate sustainable strategies and action plans.

The government needs to create standards to protect ecological integrity. This could be achieved by imposing environmental protection legislation based on the ecosystem approach, such as the pollution prevention provisions of the Fisheries Act. In addition, creating incentives, such as carbon tax in which the cost of carbon-based fuels accounts for the external environmental cost of its use, will also protect the environment and ensure efficient use of resources.

Finally, laws can create institutions to generate information and promote shared values and knowledge about sustainable development, such as the National Round Table on the Environment and the Economy (NRTEE). It could also create institutions to collect and publicly distribute information about progress towards sustainable development such as the federal State of the Environment Reporting Office, an to ensure compliance with principles of infrastructure sustainability such as the Canadian Environmental Assessment Agency and the Commissioner for Sustainable Development (29).

The law's capacity to accomplish the objectives discussed in this chapter is limited. The content and the implementation of laws depend on political will and therefore required behavioral changes and education of the society. The public needs to know the importance of infrastructure sustainable development and its impact on society.

The Council of Academies of Engineering and Technological Sciences (CAETS) urges the actions below (237):

Governments should:

- Encourage industry to develop environmentally advantageous technologies through provisions of incentives such as market-opening measures and intellectual-property protection;
- Support universities and other research institutions to develop environmentally advantageous technologies;
- Pursue arrangements for monitoring and assessing environmental conditions and their economic implications;
- Promote new generations of environmental technologies through international collaboration; and

- Recognize opportunities and limitations of technology in making international agreements on environmental issues.

According to Thom, some countries in Europe are considering legislation that will require return of products to manufacturers after use. This would introduce a new dimension into the design of products. Some major car manufacturers are already looking into this approach. Engineers in Europe are already thinking about designing buildings with components and materials that can be recycled into the next generation of buildings (237).

In Sweden, municipalities are required by national law to develop comprehensive plans that take into account land base, physical infrastructure, social factors, and environmental considerations. Swedish municipalities have the legislative power to introduce environmental standards based on local priorities and preferences, a power broadened by direct taxation mechanisms that broaden the municipal tax base (91).

Construction and Demolition Legislation

We may need to consider a regulatory approach to source separation, although it will most likely meet strong resistance from the construction industry. Governments may consider including source separation in the conditions for constant for public works.

The Canadian Federal Government established a goal of 50% reduction in solid waste generation by the year 2000 through the 1990 Government of Canada's "Green Plan". Some of the reasons that led to this goal were:

- The ever increasing rate of waste generation;
- Reduction in landfill capacity; and
- Public intolerance to the expansion of or creation of new dump sites.

However, this plan did not lead to much C&D legislation at both the provincial and the federal levels. The exception being the Ontario Regulations 102/94 and 103/94 which target (138):

- Large industrial waste producers;
- Large commercial waste producers;
- Large institutional waste producers; and
- Building construction and demolition projects with over 2000 square meters in gross floor area.

While this is a step in the right direction, it does not address the C&D waste that is generated by smaller construction projects and all renovation projects, which form a majority of the projects that take place. Another problem with this legislation is that it excludes the C&D waste generated on crown properties, which in turn excludes large waste generators such as the Department of National Defense. In addition, the general contractor is responsible for its implementation. This legislation should be expanded to C&D projects of all sizes and it must be applied to all of the provinces, and not just Ontario. Only when waste reduction is practiced in all parts of the country and on projects of all sizes, there will be a reasonable chance of change in our solid waste crisis.

9.7.3 Internalizing Environmental Costs: Policy for Urban Transportation

Public policies and public institutions tend to play supporting rather than principal roles in determining metropolitan growth patterns. Metropolitan development is driven by market forces that are only marginally influenced by regulations and public policies. The market indicates land use and transportation preferences, and public policy decisions usually are keyed to market choices. Public decision making may modify the actions of the marketplace but to a small degree. However, transportation systems offer public officials a powerful tool for influencing urban form and quality (206).

Environmental issues have assumed a growing importance for transport policy makers and the environment has moved to the forefront of the political agenda. Governments can take action in a number of ways. They can impose regulation, steer behavior by market signals through fiscal policy, and also publish information and seek to change public attitudes over the longer term.

The transport sector has been the subject of considerable government intervention, regulation and planning. Transport supply is manipulated for a variety of reasons such as achieving mobility, regional development and equity, all at the expense of the environment. While such intervention failures are known in other sectors, they are certainly severe in the transport field. Therefore, many of the current problems being faced today, are not due to traditional market failures, but are the by products of deliberate policy initiatives (19).

Since transport's contributions to global warming are the consequences of a hierarchy of decisions ranging from where and how a subdivision will be built to how to get to work today, policy responses can be directed at several levels of decision. Policy can influence (206);

- The public investment decisions that determine what kind and quality of transport options are available;
- The private investment and market decisions that determine what kind of vehicles are offered for sale;
- People's location decisions for development, homes, and workplaces;

- Vehicle purchase decisions; and
- Travel and mode choices.

No single policy instrument will solve the problem due to transportation's important and complex role in the North American economy and the magnitude of changes that would be required decrease or eliminate its contribution to global warming. Since passenger travel in cities represents the largest share of North American transport energy use and greenhouse emissions, the largest reductions in emissions will come from measures directed at reducing the energy consumed in urban passenger travel. This can be achieved by increasing the efficiency of vehicles, influencing how people travel and by what modes. Because private light vehicles are the dominant mode of travel, measures to increase their efficiency are liable to have the greatest effect on transport greenhouse emissions (206).

The national interest can be served through the development and maintenance of a sustainable program for the delivery of transportation services that strengthen national and international competitiveness, maintain national security, promote the achievement of national clean air goals, enhance energy efficiency, and improve the overall quality of life (21).

Many bureaucrats prefer the old system because they designed it have been committed to it throughout their careers. Sustainable development does not fit within the old structures since new systems will redefine turf, cross over carefully maintained departmental and jurisdictional boundaries, require new skills, new thinking, and new people. Therefore, most bureaucrats see it as a major threat.

For the past many decades, a wide variety of subsidies, both public and private, have been devised to support the automobile, which most of the drivers do not even realize. Most of these subsidies are channeled through development itself, in the form of parking requirements, fees and property dedication to roadway enlargement, etc. The best way to bring balance to the economic incentives in the transportation system is to remove them from the auto system.

Economic disincentives to road use must be increased. These should complement the effects of strong planning. Road pricing, coupled with stringent development control in and around suburbs, could reduce car use. Other elements may include increased taxation on fuel and on vehicles.

Instead of pricing emissions, governments typically attempt to control directly the amount of waste emitted. They choose direct control of the quantity of emissions rather than indirect, but more efficient, control through pricing. Sustainable development provides a difficult challenge for us all, but it also provides a unique opportunity to make changes which will create a healthier economy and environment.

Market-based economic policy instruments are firmly grounded in the legislative and regulatory system. These instruments stimulate research into and development of leading-edge technology and alternative production techniques, products and services. This form of research and development (R&D) incentive is the best type, because the market for results is established first. In addition, the proper design and implementation of market-based instruments stimulates practical and marketable R&D because the cost structure of existing environmental usage, waste, and emissions are better understood. Market-based instruments provide clear incentives to profit from environmental R&D by implying that businesses can do well by doing good (141).

An environmentally sustainable economy depends on improving the efficiency of resources use across sectors, and efficiency is largely driven by economics. Economic instruments can provide long-term advance notice of increasing stringency to industry, allowing them to evaluate new process technology and plan investment over longer periods (141).

Governments can tax, borrow, and spend, and if taxing and borrowing comprise the government's basic course of action, then economic instruments are the natural tools to use. A well designed set of market economy based policy instruments for sustainable development will allow the integration of environmental and economic factors into practical choices of everyday life (21).

> *"If environment ministers are to clean up the world cheaply, they need to make friends with finance ministers. They could show that greenery offers a wonderful chance for imaginative tax reform. Most rich countries face shrinking workforces early in the next century. The economic growth will have to come entirely from using more capital, or from technical innovation. By cutting taxes on labour, governments can remove one disincentive to join the job market; by cutting taxes on capital, one disincentive to save. But taxing the use of natural resources- be they oil, or cadmium, or the dirt absorbing capacity of the atmosphere- governments can not only pay for lower taxes on labour and saving; they can also make markets work better, by ensuring that prices reflect the full costs of economic activity...[Finance] ministers can do more green good than all their spendthrift colleagues by scrapping subsidies and tax breaks, and making sure those raw-material prices which are under their control are not set below market levels. Such policies are not just bad for the economy: they are bad for the environment, too.* (141)

The right economic incentives can encourage economic activity that is clean, efficient, and competitive, and being competitive in national and international markets is a means to prosperity. General acceptance of the connection between prosperity and sustainable development would clarify the direction our governments can take to prepare for the economic and environmental challenges of the next century. When sustainable development is thought of as an opportunity rather than a cost, the path for innovative approaches to integrating economic and environmental goals is cleared (141).

Hawken points out that, "We are so battered by the insults of the existing system that we fail to see how creative are the alternatives." (119) The economy needs to be redesigned by shifting most if not all the taxes presently derived from income and payroll taxes to taxes on pollution, environmental degradation, and non-renewable energy consumption. These green taxes or green fees would be incorporated into the price a company or customer pays for a resource, product, or service, and they create powerful incentives to revise and constantly improve methods of production, distribution, and consumption, as well as a means to reconsider our wants and needs. These green taxes would give people positive incentives to avoid them, and give people ways to respond, change, invent and innovate.

There are opportunities to build a more productivity-enhancing tax structure based on "green taxes" and other market based policy instruments. Some examples of economic incentives are (141):

- **Tradable Permits:** A cap, or planned reduction of the emission in question must be established. A system if tradable permits provides certainty for achieving environmental goals, but allows the cost to be established by the market.
- **Full Cost Pricing:** This refers to the full incorporation of all environmental externalities into the price of goods and services.
- **Full Cost Accounting:** This refers to externalities, but often means accounting for resource depletion as well as environmental externalities.
- **User Fees:** The purpose of user fees is to put the burden of cost more fairly on the specific users of the product or service rather than hiding the true cost in general tax revenues and subsidizing the heavy users at the expense of others. Examples of user fees are charging for highway travel or higher registration fees for heavier or less fuel efficient vehicles.

- **Environmental Taxes, Fees or Emission Charges:** These can be applied to virtually any undesirable phenomenon. An example would be a carbon tax set sufficiently high enough to reduce emissions significantly.

Although this section concentrates on urban transportation as an example, policy instruments for internalizing environmental costs can be formulated for other infrastructure activities as well, such as construction and demolition, where the cost of building new facilities rather than renovating existing ones would cost more, and it would cost less to reuse materials rather than new ones.

9.7.4 Infrastructure Lobby

The issue of infrastructure is a familiar one to politicians at all levels. In order to ensure that they remain aware of the challenges that have to be met, a large number of infrastructure lobby groups have been generated. The following infrastructure lobbying goals state very well the legislative achievements that the legislature should strive for in the years to come (234):

- Create public awareness of the need to increase infrastructure investment and infrastructure's role in building the nation's economy and improving the productivity of the nation;
- Promote the economic benefits of job creation through public and private infrastructure investment;
- Encourage government action at the federal, state and local levels to increase infrastructure funding;
- Encourage innovations in technology, financing, and public-private partnerships;
- Encourage formation of similar state and/or local coalitions; and
- Foster joint cooperation among the public and private sector organizations in support of resolving the nation's public works crisis.

Local governments and their representatives need to become part of the process of influencing the state/provincial and federal polices. NACO adopted an interim policy resolution on infrastructure needs in 1983, summarized as follows (240):

- Local government infrastructure needs are too large for them to handle with their current resources;

- Since county governments have the responsibility for major portions of the nation's infrastructure systems, they should be involved from the start with the development and implementation of a national policy;
- Rural and urban needs should be considered on an equitable basis in the development of national polices and programs;
- Local governments should qualify for public works grants and loans primarily on the basis of their infrastructure needs and unemployment factors;
- The federal government should move to consolidate infrastructure grants and loan programs with the goal of maximizing local government flexibility, decision making, and priority setting;
- The tax-exempt status of municipal bonds should not be changed in any aspect of infrastructure financing legislation;
- Local government matching requirements should be minimized especially for economically depressed areas with a demonstrated inability to pay; and
- Federal seed funds for infrastructure banks should supplement rather than replace existing grant programs.

Infrastructure lobbyists should be aware of the following legislative goals and pursue them (234):

- There should be no further funding reductions in existing federal programs that address infrastructure needs:
- The existing federal infrastructure trust funds must be continued, adequately funded, and fully expended for their intended purposes;
- Federal restrictions on the use of tax-exempt financing for infrastructure purposes should be eliminated;
- A federal capital infrastructure program should be created to provide assistance to states and localities in meeting infrastructure needs; and
- A federal long-term, multi-year capital budget should be established.

9.7.5 National Infrastructure Policy

The North American infrastructure system with its present laws, is not effective. Several people suggest changing the present infrastructure system legislation to solve the infrastructure crisis. However, there is disagreement on whether this new infrastructure policy should be a national policy or not.

According to some experts such as Netzer, the infrastructure crisis is a local problem rather than a national one. Deficiencies in the nation's infrastructure are not universal, but concentrated regionally and within regions. The condition of infrastructure poses problems everywhere, but these problems differ form place to place and their impact is localized. These experts do admit that some of the public capital provided by state and local governments provide benefits that spill over boundaries, particularly for environmental and transportation facilities. However, these spillovers are mostly to adjacent jurisdictions and not national in scope. Therefore, since we seem to have mostly local problems, a national infrastructure policy will not be appropriate (213).

These experts go as far as to discuss the degree to which we do need a national policy to spend money on infrastructure renewal. For instance, if the state elects not to raise adequate funds to support highway capital spending needs, is this a national problem? Some say that it might be if large portions of the highways were used for inter-state travel and long journeys. But most trips are short. Moreover, do our national concerns about energy and the environment justify a national policy? Should the government provide transportation aid to all states that encourage the shift from private to public transportation? The extension of the Surface Transportation Act in 1991, showed that the more federal-aid legislation tries to achieve those objectives that merit national concern, the more the states complain about Congress and the Administration interfering with state and local priorities. In Canada, the federal government has even more difficulties than the US in passing new by-laws or simply imposing changes. What is then the advantage of a national policy?

Instead of a national policy, these experts propose the decentralization of public works as a possible solution to the infrastructure crisis. Decentralization can be defined as the transfer of responsibility for planning, management and the raising and allocation of resources from the central government to the local governments, private enterprises and non-governmental organizations. There is a general consensus that such organizations can manage the infrastructure and deliver the services to the community in a more efficient and effective way than the central government (173). There are four types of decentralization (203):

- **Deconcentration:** It is the redistribution of administrative and financial and management responsibilities for providing public services and infrastructure among different orders of government and/or within the central government. It is often considered the weakest form of decentralization.
- **Delegation:** Through delegation, central governments transfer

responsibility to semi-autonomous organizations not wholly controlled by them, but ultimately, accountable to them, such as municipalities.

- **Devolution:** This involves transferring responsibilities for services to the municipalities that raise their own revenues and make their own investment decisions.
- **Privatization:** This encourages and allows services to be provided by businesses, community groups, cooperatives, small enterprises, etc., under the authority of governments.

Although centralized decision making has been questioned by many due to its inability to take into account local needs, circumstances and environmental sensitivities in infrastructure investment, operating, or pricing decisions, it can still play an import role in infrastructure planning and management in the following ways (91):

- Setting technological and pricing standards for pricing, thereby facilitating its implementation;
- Coordinating planning and delivery of land use and physical infrastructure in major metropolitan areas covering several municipal jurisdiction; and
- Developing national environmental standards for various types of infrastructure facilities, energy efficiency, etc.

However, infrastructure for most people, while largely a local matter, has strategic national importance. The society's productivity and the quality of life depends on local infrastructure. Aschauer has attributed as much as 60% of the decline of US productivity since 1960 to the shift in government spending priorities away from public works. As a result, a national infrastructure policy is necessary (153). Besides, federal involvement is crucial since the federal government and other national agencies play an important role in developing standards such as the National Building Code, which may be adopted by provincial and local regulatory agencies (96).

Despite the fact that infrastructure is crucial for the nation's economy and standard of living, there is no federal agency responsible for infrastructure policy. The responsibility, is instead, distributed among several federal agencies that have independent roles in the development or regulation of specific modes such as transportation, energy supply and transport, telecommunications, and water resources (151). There needs to be a federal strategy for public works infrastructure renewal and R&D. Its absence usually results in each infrastructure component being considered independently of other components, in policy, planning, and execution (40).

The government should create an institute or a ministry on infrastructure alone, which shall be responsible for planning, constructing, operating and maintaining infrastructure. It would also provide leadership in the national evolution of infrastructure policy and will be the point of contact for international exchange on issues related to global infrastructure needs and impacts. Finally, it would be a clearinghouse for research and development information exchange and perhaps for limited funding for policy-related researches.

The institution would also have to establish a national infrastructure needs assessment program after making an inventory of all existing facilities. In addition, it will have to create its own national code of infrastructure for the design, construction, operation, management, and maintenance. This could be done by reviewing the existing technical standards. Such a national infrastructure code would provide the following benefits (153):

- Improve industrial productivity and competitiveness by promoting the wide spread use of cost-effective technologies; and
- Reduce interprovincial and municipal barriers to the creation of a larger, more uniform domestic market.

The national infrastructure policy should assert that the nation's infrastructure should be managed in a coordinated manner to provide optimum services. This could be achieved by forging strong links between the infrastructure institute and the local and state/provincial governments which are more aware of local needs. Municipal governments have to be involved in the decision making process and the selection of projects to be built, replaced or rehabilitated (153). This would require that municipal official such as the municipal engineer, the councilors and the mayor, be aware of the infrastructure crisis and the importance of its renewal. People in charge need to take initiatives that benefit the society in the long run, even if they go against the people's will. For instance, the liberal party decided to focus its national policy on deficit reduction while most people were in favor of creating more jobs. Although job creating is very important, it is a short-term solution to our economic decline, while deficit reduction has long-term implications.

The national policy has to promote and implement a strategy focused on repairing our existing infrastructure, rather than constructing new facilities. It should consider not issuing construction permits to projects that do not have any maintenance policies and budgets, and/or do not use alternative funding financing mechanisms.

Finally, the policy should assure that resources are directed to solving problems that fall outside the capabilities of state/provincial and local governments, such as infrastructure banks in the US.

9.8 SUMMARY

Today's infrastructure problems require innovative solutions that take into account the national spending trends, the federal deficit, and individual state/provincial needs. Legislation efforts should focus on the development of state/provincial programs to manage and leverage public financial resources, and to attract and facilitate investment of private capital. This would require, among other things, technical assistance to the governments in making financial decisions. Creative legislation at the federal and state/provincial levels, offers one of the greatest promises for long term, coordinated, and flexible solutions to the infrastructure crisis (61).

Progress towards infrastructure sustainable development will require systemic integration of environmental, social and economic considerations in ongoing decision-making at all levels of society. Law reform can play an important role in promoting this integration by introducing new ideas, creating new structures and mandating new processes. However, we should not wait for legislation to pass before acting. Legislation will only be introduced or passed if there is political will and public support.

Even though not responsible constitutionally, the federal government is morally responsible for preserving our national infrastructure. The input of local and state/provincial governments is also needed since they are more aware of local needs and more efficiently maintain infrastructure facilities. Lobby groups and other organization such as the FCM and NACO are essential to the ensure upkeep and continued financing for the infrastructure. The problem however, is that lobby groups should try and educate all parties involved and not just the federal government. For instance, the FCM targets the federal government for more funding but fails to educate its own members from wasting existing resources and adopting new and innovative techniques for infrastructure renewal. Its focus is too limited in trying to raise money for its members and should also turn toward the municipalities that it promises to serve and have them change their ways.

Most importantly, since the federal government does not have any funds to direct towards the infrastructure and cannot afford to reallocate resources form other federal programs, it should work on a national infrastructure policy needed to provide a framework for solving the current infrastructure crisis. This policy should establish recognition of the nation's importance of local infrastructure and enforce the principles of life cycle costing through national building codes. The federal government should also help find alternative forms of financing and create public awareness about the infrastructure crisis.

It should be pointed out that the US is far ahead in recognizing the infrastructure crisis and implementing policy and legislation in this regard. Canada's record is poor compared with the US and it must follow its neighbor, although it would have been expected to take the lead instead. It should learn from the US success and failure in infrastructure related matters. Why is it that an Infrastructure Bank sprang up in the US in the early eighties, and we in Canada are not even thinking about it. The US recognizes the importance of a safe, reliable, and efficient infrastructure to its economy and society, while Canada on the other hand, only turns to it when it wants to help create more jobs. It's time the politicians woke up and did something about the crisis that is going to haunt our children and grandchildren. Although, we must not stop at blaming the politicians at being so ignorant. What about the civil engineers who know about the crisis and are in the position to lobby and educate the public officials in charge of our infrastructure. The role of the engineer with respect to the future of the infrastructure will be discussed in Chapter 11.

Global change may be the most important legacy we can leave to our descendants. It raises difficult questions of equity between the present and the future generations. Laws and institutions shape our contribution to global change and our response to it. Used wisely, they can slow the rate of change, mitigate long-term damage, and facilitate adoption. Global change raises legal issues which deserve particular attention and which have either been overlooked or are traditionally difficult to address (223).

10.0 INFRASTRUCTURE'S FUTURE NEEDS: R&D AND INNOVATION

10.1 INTRODUCTION

Public spending on infrastructure generates growth in the private sector. Infrastructure renewal is necessary for maintaining and enhancing prosperity for infrastructure facilities which are an integral part of our political, social and economic life. They are responsible for the quality of our water supply, transportation systems, buildings, safety of our waste removal and access to electricity and communication systems.

It is now clear that our infrastructure is in a crisis. It must be maintained if we are to compete in the global economy and maintain our standard of living. This can be achieved in an effective and efficient manner if we avail new technologies and encourage further research and development in the infrastructure technology. The adoption of new and appropriate technologies will not only improve the infrastructure efficiency but will also reduce the cost of new construction.

We must also question whether our existing infrastructure is adequate to serve the nation, if maintained properly. We need new ideas and new systems to ameliorate the condition of the infrastructure. The importance of innovation, research and development (R&D) in the effective maintenance of infrastructure needs to be encouraged. Only this will enhance the contribution of the infrastructure to our health , environmental quality, safety and economic welfare.

This chapter will discusses research, development and innovation in infrastructure and sustainable development and also attempt to identity the future research needs by summarizing priorities listed by the US Office of Technology Assessment, National Science Foundation, Civil Engineering Research Foundation, the Federation of Canadian Municipalities, and the author.

10.2 RESEARCH, DEVELOPMENT AND INNOVATION

Knowledge is a key contributor in the development and technological advancement of a country. This knowledge is a product of R&D. " ...the real engine of long-term growth is knowledge... And the more Canada invests in R&D, innovation and education, the stronger the foundation for growth" (15).

10.2.1 Technological Innovation

Because infrastructure demands high capital costs and long-term maintenance, any improvements in construction practice can have highly beneficial impacts. The adoption of efficient and up-to-date technologies can dramatically improve efficiency and reduce costs of both new construction and repair. The need to develop new technologies supports investment in Research and Development.

Innovation and research and development help a society maintain a certain level of service or improve it. Today, people in general have high expectations of service from the infrastructure. There is a high expectation for a safe and secure electric supply, safe drinking water, protection from lake or river contamination or environmental damage, etc. (90) Older areas of development generally have a lower level of service than newer developments. But when infilling occurs in the older areas, a higher level of service is expected, because the user expectations have been rising continuously, and the pressure on the politicians to provide such levels of service are mounting. This pressure is then turned on the planners and the engineers. Are the engineers and planners able to provide the levels of service required or demanded? Only further innovations in infrastructure will ensure a better standard of living and higher levels of service.

Most North American infrastructure construction and rehabilitation methods have not changed much in the last 30 years and most of present infrastructure relies on technologies that were initially developed in the 19th century and the first half of the 20th Century. Change in infrastructure technologies should be more rapid and this can only be achieved by means of a strong commitment to research and development. After all, countries taking the lead role in developing more cost-effective processes and materials will provide their industries with a competitive edge.

Technological innovations involves both tools and procedures, products and processes, interacting in new ways. Technological innovation can be considered (41):

- A new product;
- A new process of production;
- An improvement in the instruments or methods of planning and implementing innovation;
- A substitution of a cheaper material, newly developed for a given task; or
- The reorganization of production, internal functions, or distribution arrangements, leading to increased efficiency, better support for a given product, or lower costs.

The initial capital and maintenance costs of municipal infrastructure depend both on the cost of the technology used to build it. The development, implementation, and maintenance of our infrastructure facilities depend on a combination of knowledge, materials, equipment, and skilled individuals. Innovative up-to-date technologies contribute to safe, efficient and effective service and to economic growth and the quality of life. Outdated technologies may endanger public safety, increase the cost of service, and reduce the competitiveness of business and industry. In addition, spin-off products, processes and expertise contribute to the national export potential.

Since World War II, the federal government has been the primary sponsor of all research and development (R&D) in the US, currently providing about 43% of the R&D spending. Some private firms conduct informal in-house R&D for new product development, and may compete for government sponsored research funds. Their estimated R&D spending is less than 0.05% of their sales. The total annual US R&D spending on infrastructure related technology is approximately $2.1 billion, as summarized in Table 10.1. This amount is approximately 1.6% of total estimated US R&D spending.

Table 10.1: Estimated Aggregate Infrastructure R&D Spending in the US (41)

Source of Funds	Estimated Annual Amount ($)
Federal government	1.206 billion
Private sector	
Construction industry	230 million
Equipment manufacturers	600 million
Service companies	88 million
Design and management companies	15 million
Total infrastructure R&D spending	**2.139 billion**

The US construction industry lags behind the other industries in productivity gains and in resources related to research and development. While non-defense related R&D investment in other US industries such as telecommunications, aerospace, chemicals and automotive, runs between 3% and 4% of total expenses, the construction industry investment in research is less than 0.5% (105).

There is significant involvement of the industry in infrastructure related construction R&D in industrialized countries in Europe, compared to that in the US, estimated at less than 0.1% of annual construction volume. European industry participation is estimated to range from 20 to 80% of the total construction R&D. In addition, in Europe, the construction industry cooperates extensively with the universities and research institutes and is actually a principal source for applied research funding (40).

Empirical studies show that R&D tends to create improvements in the well-being (social returns) that are much larger than the private returns to the organization undertaking it. Between one-third and two-thirds of the economic benefits of R&D are not realized by the organization that performs it. The social rate of return on investment in generic knowledge is of the order of 30-50% of the total investment. Private returns refer to the gains realized by the organization undertaking the R&D program, while social returns are based on the total benefits, including those flowing to consumers and other producers (207).

Spillovers depend on the nature of R&D undertaken. Basic scientific research, which can stimulate a wide range of new products and process innovations, will have a very high spillovers over an extended period of time. However, the gap between social and private returns will be much lower for minor innovations that are aimed at solving the specific problems of individual producers (207).

Firms operating in competitive and fragmented industries such as construction, are less able to translate their innovations into higher profits than firms that possess some degree of market power. Consumers in the construction industry have been experiencing steadily rising costs due to the industry's slow technological evolution and has, therefore, been unable to compensate for labor and material cost increases (207).

10.2.2 Management of Technological Innovation

Information and knowledge are the essential foundations for innovation. Some of the mechanisms for the creation and dissemination of knowledge are (36):

- Basic scientific or engineering research:
- Collaborative research between public and private sectors;
- Tax credits for company R&D;
- Education and training providers;
- Levy/grant systems for research;
- Information infrastructures such as infrastructure libraries, databases, electronic networks etc.;
- Professional institutions for transfer of knowledge, trade associations and industry research bodies; and
- others.

Professional and industrial associations will have to commit resources in order to educate their members and the public that innovation in construction is the key to the welfare of this economic sector and to the country. This establishes a need for an increasing number of government/private sector partnerships and consortia with a broader scope.

Research takes place at the universities, government agencies or specialized organizations, and it does not work well under such circumstances due to lack of coordination and repetition of research. Therefore, current trends towards multi-participant private sector/government partnership should be increased and expanded, bringing the various parties together, forcing relevance and ensuring some technology transfer. Higher levels of interaction between the various participants can be promoted by (36):

- Mandatory continuing education;
- Training/apprenticeship;
- Periodic re-certification;
- Higher requirements at the entry level; and
- Greater movement of people between the practice and academia.

Since there are significant levels of technical, legal, and financial risks involved in introducing innovation into practice, the risks should be shared. Projects should be cooperative and technology should be tested and evaluated outside the laboratory to help tear down some of the current barriers (23).

In order to reduce the average time to market for innovation, relevant national and international construction and engineering organizations need to establish an international foundation to set the framework for developing research and innovation strategies that can be applied on a consistent basis. Collaboration could be promoted by the establishment of an international clearinghouse to channel communication. The proposed foundation would develop prototypical best practice partnership agreements, perform an analysis of "best practices" for current collaborative models, establish an information exchange network, and facilitate the establishment of international construction goals.

Innovation can be improved in the construction industry through encouraging wider use of innovative demonstration projects. This could be aided by an international resource center that would collect, exchange and disseminate information about demonstration projects. The center, which could also be an international network of national centers, would also provide assistance and support to those considering establishing demonstration projects. First, a manual of best practice for establishing demonstration projects, would need to be established. This manual should be regularly updated and could include information on partnership arrangements, mistakes to avoid along with examples of successful projects, and promotion strategies for demonstration projects (38).

There is a need for a centralized organization responsible for focusing efforts on infrastructure problems and helping to introduce innovation into practice. Current efforts are too fragmented and success will only be achieved by sharing research results and accepting practices from other regions and countries. The various parties, whether they are private companies, government agencies or universities, need to be united with the potential users of the new technologies, such as federal, state, and local agencies, and private contractors.

Bernstein, believes that there are two very powerful methods, used in other industries and countries, that we need to use to stimulate innovation and unite the fragmented design and construction industry. They are referred to as consortia and consensus-based processes for the evaluation and acceptance of innovation. These methods bring together people with different needs who can benefit through cooperation (23).

Consortia

The consortia process allows a variety of public and private organizations of all sizes to join together at different stages of a specific project with limited risk and investment. Consortia are also a way to bring the expertise in our academic community together with the needs and resources of industrial partners. The cost and risk to the companies are minimized, while the benefits are maximized. This method enables private companies to maintain their competitive positions in the marketplace through the development of their own products and services. In addition, government participants have first access to the latest technologies for public-sector projects, while working toward national technology policy goals (23).

Consensus-Based

The consensus-based process represents unprecedented alliances between all levels of government, private industry, academia, research organizations, and other key elements of the community. This process is increasingly being used to evaluate and introduce innovation into the marketplace through the establishment of cooperative agreements between federal agencies, using existing national laboratories, university-based research institutes, and private companies. New technologies tested in the laboratories can be introduced to practice. This process allows the risks of introducing new products, to be shared more equitably, thus encouraging research and innovation of new products. Innovators, private companies, or pubic entities with new products can work with technical panels organized to plan and implement the evaluation and testing efforts to demonstrate to the product safety and its demonstrated benefits (23).

10.3 BARRIERS TO INNOVATION

There are several reasons for the lack of research undertaken in the broad areas related to the infrastructure, basically because of the complexity of the infrastructure systems due to economic, geographic, political and technical factors.

Innovation in construction is a complex issue since it is a long-term and non-linear process. In addition, the cost and quality of built goods and services does not improve at the same rate as in other industrial sectors. The cost of building materials is going up due to the environmental requirements and increasing scarcity. Better quality and lower costs can be achieved only through an improved knowledge base of existing and new technologies.

The R&D establishment is very conservative and skeptical to rapid change. There is also a great deal of difficulty in working together for innovative solutions due to barriers in (36):

- Perception of long-term research investment vs. short term commercial objectives;
- Reputation vs. bottom line;
- Scientific achievement vs. project risk;
- Legal liability; and
- Physical distance between the knowledge developers and the performers.

10.3.1 Barriers Faced by the Construction Industry

The construction industry has many barriers to overcome such as (36):

- Lack of understanding by the senior management;
- Industry fragmentation;
- Risk aversion and compartmentalization;
- Single contract risk/reward imbalance;
- Difficulty in estimating benefits;
- No clear market force;
- Expectations to recover investment on single projects;
- Adversarial relationships;
- And others.

Other barriers of innovation in engineering and construction are (36):

- Professional tradition of continuing to do things as they have been done in the past;
- Lack of incentives that can motivate change and develop commitment to steady improvement; and
- Organizational traditions that deter innovation and risk-taking.

Due to the numerous barriers mentioned above and the high number of players involved, new technology is not being brought forward at a desired rate. In addition, innovation in the construction industry faces the following barriers due to the nature of the constructed products:

- Immobility: production occurs at the construction site;
- Complexity: since most of the required material are finished products, increased specialization is required;

- Durability: since most construction materials are required to be durable over a long period of time, they wind up being bulky, heavy and conservatively designed;
- High cost: due to increased complexity, increased quality, and low productivity; and
- High degree of social responsibility: due to concern for public health and safety and concern for the environment.

The development and diffusion of new technologies face barriers due to the segmentation of the construction industry. The several types of segmentation include:

- Type of owner: public or private, frequent or infrequent;
- Type of facility constructed;
- Size of the facility;
- Scope of services required; and
- Geographic location.

One of the reasons that construction firms do not support research and development is due to the risk involved. Individual firms act in their own self interest and are unlikely to invest in research and development. Research and development is considered risky because its outcome is unknown, and the construction industry is one of the riskiest of all industries. The risks of bidding are very high, but most contractors feel that they can control them, and the rewards are direct and tangible. However, they feel that the risks of research and development are uncontrollable and the rewards are indirect and intangible. Contracts are almost always awarded based on price rather than the experience and eligibility of the construction firm. This reinforces the risk and the contractors stay away and are not interested in experimenting with new technologies.

Since innovations in engineering, design and construction are often related to processes, unlike products, they are not always patentable. Therefore, the motivation to develop new technologies is not present since the financial rewards are almost non-existent. Therefore, focus should be on obtaining patent rights, protecting trade secrets, or other form of intellectual property rights, in order to encourage innovation and technological change. This would allow inventors to protect their inventions and to profit from their economic benefits.

The government also creates barriers for the construction industry to adopt or develop new technologies. Government disincentives include (36):

- Tax structures that discourage investment, including double taxation of earnings and dividends, long depreciation periods, high capital gains tax rates, and taxes on projects under construction;

- Government procurement regulations that prevent recovery of the development costs;
- Tariffs and hidden barriers to trade;
- Building codes and regulations; and
- Laws regarding liability and contractual relations in construction.

10.3.2 Barriers Faced by Management

There are several barriers to successful and effective management of design and construction projects such as (36):

- Competitive and inconsistent goals;
- Lack of trust among the stakeholders;
- Conflicts arising between sustainability requirements and free enterprise;
- Government procurement practices which insist on the lowest bidder;
- Litigious atmosphere;
- Lack of design and construction quality;
- Poor identification of project requirements by the owner;
- An inadequate project budget;
- Poor communication among the various stakeholders; and
- Varying financial incentives.

In addition, the creation of comprehensive, persistent and seamless decision support systems is a complex process that faces the following barriers (36):

- Communication modes are varied and distributed;
- Human prejudice based on past experiences of the individuals involved;
- Lack of availability of operational models for a diverse set of decision makers to work together, sharing information and making decisions; and
- Tools available are not efficient in overcoming professional and trade barriers, providing databases and enhancing ease of communication between remote sites and disciplines.

10.3.3 Industry Fragmentation

There is no single government agency or organization responsible for looking after infrastructure in both Canada and the U.S. Each type of infrastructure has its own set of institutions with different degrees of receptiveness to innovation. In addition, there is a division of responsibilities within some facilities such as the highway system in which all levels of government play diverse roles. This fragmentation leads to (34):

- Problems in initiating and conducting research programs.
- Most agencies have little or no resources available for research due to their small size.
- There tends to be an uneven distribution of resources due to the fact that the different agencies serving the same type of infrastructure compete with each other for the same resources.
- Since there is little or no cooperation or exchange of information between the agencies, a lot of research programs get duplicated.
- It is almost impossible to conduct research that cuts across the different types of infrastructure that face similar problems such as the wastewater, water supply and hazardous waste industries encountering problems with piping design. More collaboration efforts are needed.

10.3.4 Absent Market Mechanisms

Some of the reasons responsible for the lag in infrastructure research relate to the market served by the agencies responsible for infrastructure (34).

- Private industries are reluctant to invest in innovative products unless there is a large market for their products; and
- The marketing costs faced by private industry are too high and further discourage infrastructure research.

10.3.5 Cultural Values

Consumers themselves pose major barriers to innovations at times. People in general find it very difficult to change their old habits, so new infrastructure technologies cannot become efficient and part of our lives. The two most common examples are (34):

- **Transit systems**: Most people are very attached to their cars and their reluctance to switch to other modes of transportation makes it very difficult to make improvements in mass transit systems or to efficiently use what already exists.

- **Waste disposal**: We possess a cultural tendency to dispose of our waste, rather than reuse it. There is reluctance to separate waste such as glass and paper at the consumer level. This makes it hard to develop technologies to improve the maintenance, management and modernizing of existing infrastructure.

10.3.6 Large Project Scale

Most infrastructure facilities are (34):

- Costly;
- Large-scale;
- Complex;
- Geographically dispersed; and
- Required to provide reliable services and products for a long duration (50 to 100 years).

These systems require research developments that are large-scale, complex, expensive and long-term. This in turn makes it very difficult to get support for research development in jurisdictions having short-term political agendas and limited resources.

10.3.7 Risk and Liability

The current litigious society is a strong barrier to innovation and productivity in civil engineering, and has become a disincentive to the introduction of new technology and processes into practice. As a result, North American competitiveness in the global market continues to deteriorate. Risk and liability lead to low-risk designs (105).

Engineers are now facing more and more liability suits which is pressuring them to fall back to following conservative design practices in the design and construction of infrastructure facilities. The problem is further increased by the current traditional contracting process which spreads the work of one project among several companies. Different companies wind up doing the initial design, final design, construction and construction management. This in turn makes it very difficult for the preliminary designers to suggest or practice innovative design techniques since these techniques may requite careful field installation and they may not be able to supervise the implementation of their special designs.

All this produces a very expensive infrastructure facility since over-conservative decisions are made at each level of the contract process resulting into an over-conservative total design.

10.3.8 Standards and Regulations

Although standards and regulations are essential for assuring both safety and reliability, they also pose barriers to innovation if not revised on a regular basis. Many existing standards, such as those in the highway systems, were formulated at the turn of the century and have difficulty accommodating new design, construction and material methods. There is for some reason a great reluctance to update long established building standards.

Another barrier for innovation is the fragmentation in the standard setting and regulatory authorities. To construct some new facilities, one may be required to meet several federal, provincial, municipal and other organizations with overlapping jurisdictional authorities.

Problems of inadequate standards are encountered in the bidding and contracting processes. Bidders are usually reluctant to introduce new products, materials and techniques, in case their bid is rejected by the contracting agency for not fulfilling the required standards. The chance of losing the bid puts great pressure on the bidder and makes it very risky for the bidder to introduce innovation in the construction of new infrastructure facilities.

Therefore, it can be seen that even if new technologies are developed in the field of infrastructure, there will be reluctance to use them in the design and construction phase due the risk of not meeting the existing standards and losing the contract as a consequence.

10.3.9 Education and Research Systems

At universities and colleges, infrastructure education is provided typically in the following departments:

- Civil Engineering;
- Architecture;
- Urban and Regional Planning; and
- Public Administration Programs.

The primary source of this education is civil engineering and even here there are barriers to infrastructure innovation due to:

- An emphasis on the design of new facilities and structures rather than the maintenance of the existing ones.
- Lack of sustained funding for research.

The emphasis on the theory and methods of infrastructure design is prominent in both civil engineering education and practice. There is only a brief treatment of topics such as implementation, operation, preservation, maintenance, and rehabilitation. Similar emphasis also exists in the other fields mentioned above.

There is also a similar trend in research that is carried out in civil engineering. There is not enough research being undertaken on materials and methods needed for effective operation, rehabilitation and preservation of infrastructure. Research in civil engineering also lacks sustained funding. Very little research is supported by the private or public sector in this area, although the interest is growing.

10.3.10 Lack of Private Research and Development

There is a lack of private R&D in the area of infrastructure in North America. However, other major developed nations such as Japan and Germany invest heavily in the development and maintenance of their infrastructure. The key point to note is that this investment is not at the public level only, but to a greater extent at the private level. Private firms invest heavily in new technologies related to infrastructure. They are also encouraged by their governments.

The North American scene is quite different. The U.S. is still better off in R&D, but Canada is in great trouble. There is very little research activity at the private level, although the work being undertaken at the public level is not encouraging either. Some blame this on a lack of Canadian entrepreneurs, while others on a lack of encouragement from the government. Most firms that do invest in R&D do so with a short-term agenda. The size of their investment depends on how much their company will benefit in the short run, rather than how their work will benefit the society as a whole (15). But it is quite obvious that there is lack in awareness of the seriousness of the infrastructure problem and its direct relationship to our standards of living and economic competitiveness.

The various governments have not yet taken this issue seriously and are therefore not encouraging enough research activity in the area. The Canadian society has not yet realized the importance of our infrastructure and its relationship to our international competitiveness and high standard of living. Only when we realize the grave consequences of infrastructure neglect as a society, we will realize the importance of research and development in the area of infrastructure.

10.4 OPPORTUNITIES, CHALLENGES AND FUTURE NEEDS

Participants at the 1991CERF Civil Engineering Research Needs Forum, identified and ranked the following 10 high-priority research topics in the area of public works infrastructure revitalization (41):

- Developing tools to make smart management decisions;
- Finding new ways to finance infrastructure systems;
- Extending the useful life of the infrastructure;
- Protecting bridges from natural hazards;
- Identifying structural problems through diagnosis;
- Removing institutional barriers to innovation;
- Economic benefits from public works investments;
- Improving water-resource systems data through new technology;
- Mitigating coastal damage from natural hazards; and
- Protecting dams against earthquakes and floods.

The NSF conducted an extensive study of infrastructure systems and with the advice of experts drawn from industry, academia, and government, produced a comprehensive report in 1993 on strategic issues and a focused set of program components for its program in "Civil Infrastructure Systems". The following is a summary of these strategic priorities (41):

Goals - Strategic Priorities

- Stimulate infrastructure renewal;
- Regain international competitiveness through excellence in research and accelerated knowledge transfer;
- Mitigate barriers to knowledge transfer through improved insight into the information utilization process and the development of innovative strategies to overcome the technical, institutional, social and legal barriers; and
- Develop new knowledge for infrastructure renewal that is reliable, safe, cost-effective and environmentally sensitive, and that would contribute to the increased productivity and industrial competitiveness of the nation.

Strategy: Integrating Priorities

- Perform knowledge utilization research through multidisciplinary programs including the social sciences, engineering, and scientific disciplines;
- Initiate research programs to address the intellectual challenges associated with the development of new knowledge and implementing existing knowledge;
- Develop partnerships with industry through proof-of-concept research;
- Support research and education at universities; and
- Develop human resources necessary to renew and maintain the nation's infrastructure.

Program Components

• **Knowledge utilization research:**	• Identification of complex infrastructure systems; and • Public-policy, legal, and financial barriers.
• **Scientific and engineering knowledge:**	• Deterioration science; • Assessment technologies; • Renewal engineering; and • Institutional effectiveness and productivity.
• **Knowledge transfer:**	• Proof-of-concept research; • Innovative transfer mechanisms; • Education and training; and • International cooperation.
• **Program mechanisms:**	• Infrastructure unit; • New and existing research centers; and • Partnerships with government agencies and the private sector.

10.4.1 Solid Waste Management

The cost of municipal solid waste disposal is rising at an ever increasing rate. Some of the areas in solid waste disposal that can be examined and researched are (34):

- Reduction of waste at the source by encouraging people to separate glass, paper and metals;
- Encouraging less wasteful packaging of consumer products;
- Rugged and reliable instrumentation for on-line monitoring of incinerator stack emissions;
- Stable sensors for monitoring soil and water contamination;
- Improving the quality of stack emissions by controlling vaporized metals, dioxins and sulfur dioxide;
- Fluidized bed combustion with gas turbines for improving gas emissions and improving the quality of air simultaneously;
- Adequate treatment of incinerator cooling water prior to discharge;
- Encapsulation or vitrification of incinerator residues to prevent leaching from landfills which in turn prolongs the life of landfills; and
- Acceleration of biological stabilization with the use of genetically engineered bacteria.

10.4.2 Municipal Wastewater and Water Pollution Control

New wastewater treatment and collection technologies, policies and strategies are needed. Research to improve the existing maintenance and management techniques helps protect the existing systems and offer improved operating performance and efficiency. Some areas requiring examination and research are (34):

- Training of personnel working for wastewater and water facilities;
- Development of effective programs for preventive maintenance;
- Development of variants of the conventional activated sludge process to yield significant short-term benefits with reduced tank volume and air supply. These variants include:
    - Step aeration;
    - Modified aeration;
    - Activated aeration; and
    - Short-period aeration;
- Further enhancement of mathematical models used for predicting the response of interrelated waterways to pollutant loads of varying strengths at different sites. These models can help allocate scarce resources to yield maximum benefits by identifying the severity of pollution problems;

- Development of alternative systems to deal with hazardous and toxic materials in wastewater streams and with pollution from agricultural sources;
- Biotechnology innovations can include:
    - Poison-resistant bacteria for centralized wastewater treatment facilities;
    - Organisms capable of digesting, trapping and neutralizing toxic and hazardous materials; and
    - Organisms capable of neutralizing wastewater contaminants from both concentrated and dispersed sources in a more efficient manner.

10.4.3 Transportation

During the past two decades, there has been a drastic increase in the work force, private vehicles and suburban employment which have shifted the demand for urban transportation quite drastically. The current level of growth has outpaced the current transportation infrastructure capacity. Some areas that need research and development are (34):

- New ways of operating old facilities;
- New ways of designing completely new facilities;
- Operation of arterial streets as limited-access roadways for short periods to serve demand or emergency conditions by means of a computerized traffic control. These systems use adaptive control based synchronization schemes at certain detection points or during certain parts of the day;
- Further research and development of software and hardware systems to coordinate streets with several intersections;
- Development of management systems to account for the inventory of infrastructure facilities;
- Eliminating and avoiding concurrent repairs to infrastructure systems by exchanging information among computerized databases;
- Enhancement of transportation by combining financial, operational and technological strategies. Examples of these are:
    - Data management;
    - Traffic signal electronics;
    - Signal systems communication;

- High occupancy vehicles (HOV);
- Analytical and simulation modeling; and
- Car and van pool marketing strategies.

- Reduction of congestion using:;
  - Automatic Vehicle Location (AVL) which enable the driver to be guided through the highway network along the alternative routes; and
  - Route Guidance Systems (RGS) enable the drivers to communicate their desired route and then receive instruction on a preferred route.
- Automated Guideway Transit (AGT) reduce operating costs due the reduction in labor.

More research needs to be focused on strategies to reduce the energy and environmental impacts of urban form and how to provide a sufficient range of energy efficient and non-polluting transportation choices. The following are some areas of research that deal with transportation, land use and urban design (21):

- What land use patterns are most efficient in serving total mobility needs?
- What densities and development characteristics support which modes of transportation?
- What type of mixed uses minimize travel demand?
- Is single-use zoning a mistake due to its heavy demand on transportation services?
- What are some successes and some failures of single-use and mixed-use zoning?
- Fuller understanding of the nature of the potential conflicts among transportation, air quality, and land use planning.
- How federal and state/provincial transportation policies and programs can resolve these conflicts?
- What are the costs to the public of uncoordinated transportation, land use, and clean air planning?
- How can funding decisions and planning be brought together to achieve regional air quality and energy efficiency goals?
- What is the connection between energy price and vehicle use?
- How important is energy price to modal choice?
- At what price do alternative fuels become economically feasible?

10.4.4 Non-destructive Evaluation of Infrastructure

Non-destructive evaluation (NDE) of infrastructure refers to procedures that utilize probing radiation such as (34):

- X-rays;
- Ultrasonics;
- Radar.

These devices monitor the performance of a particular facility and help improve the system reliability. Their most common use is in concrete structures such as highways, bridges and buildings, which frequently have serious problems with:

- Air pockets;
- Cracks;
- Corrosion;
- Voids;
- Grouting joints; and
- Permeability.

10.4.5 Design

New hardware would need to be developed for designers since the currently available CAD system hardware cannot display full sheets of drawings and cannot produce much larger images at affordable costs. New CAD displays and other innovations can be developed by private enterprise. International collaboration to develop and adopt design database standards is likely to yield very cost-effective results and contribute directly to achieving sustainable development.

New analysis tools and approaches to design will be needed for achieving sustainable development and understanding how things work in economic, social, political, and technical terms. These new tools will be very useful for understanding the overall life-time behavior of existing facilities. If designers are able to forecast behavior of existing facilities and to assess more accurately the consequences of rehabilitation and renewal of infrastructure and buildings, there will be a more efficient use of existing assets and considerably reduced waste. Some future needs in design are (38 & 79):

- **Reinvent design concepts:** Need to develop and document principles of the design process that will transform current development patterns to a more sustainable built environment. This would require the different stakeholders to define sustainable development patterns, practices, and measures pertaining to design, and establish new processes, guidelines and tools for the design industry that reflect these issues;

- **Share sustainable design knowledge base:** Need to establish an international clearinghouse through the collaborative efforts of the design industry and government, and exchange information on the design principles and practices;
- **Consensus performance criteria for sustainable development:** Key stakeholders need to establish consensus on sustainability in facilities and to develop methods for defining, benchmarking, measuring, monitoring, and disseminating results. There is a strong need to share relevant information, which could be managed by a lead organization and disseminate the results to industry; and
- Extending the useful life of infrastructure;

10.4.6 Materials Technology

For infrastructure to be able to meet the demands of a rapidly developing world, new construction systems will be needed in the following sectors of our built environment (36):

- Residential;
- Commercial;
- Institutional;
- Industrial; and
- Public works.

Most facilities that are constructed today utilize structural materials, components and connections, for whom research was carried out over the past several decades, and under the current conditions, it is difficult for the industry alone to develop and apply new materials and innovative structural systems. The process of developing new innovative systems needs an inter-disciplinary collaboration of design engineers, construction professionals, materials engineers, and experts on durability. It is very rare for a materials engineer to be involved in construction projects during the design phase, and in addition, little consideration is given to designing buildings keeping their reuse and demolition in mind.

The North American construction industry is quite reluctant to adopt new materials or invest money in developing new ones. Japan and Western Europe, on the other hand are more open to new materials and technological innovations since their governments take a leadership role in offering incentives for industry to work as a team with the government and their universities in pursuing new materials and technological innovations.

Implementing life cycle engineering is not an easy task since there is a lack of available information needed to develop the required models. In some cases, historical data is missing and in others, it is inaccessible due to its volume, location or format. The current codes and standards also constrain an engineer from adopting innovations and responding to unusual conditions. In addition, the fragmented nature of the industry also poses a barrier since different parties are involved in the designing, building and operation of structures, and very often, there is no communication or concern for sustainable development among these parties.

The recent emergence of new materials and processing techniques have contributed significantly to the infrastructure technology. Some of these new sophisticated materials and techniques involve (34):

- Glasses;
- Ceramics;
- Superalloys;
- Membranes;
- Composites having characteristics of different materials;
- Coatings;
- Advanced factory fabrication; and
- In-situ processing techniques.

Other high-performance-material applications are (41 & 229).

- Polymers;
- Advanced materials;
- Advanced components;
- Connections;
- Building systems;
- Mechanisms, models, and data for life-cycle performance;
- Assessment and quality assurance technologies;
- Renewal engineering;
- Recycling and reuses;
- Assessing consequences of materials innovation (61).
- Geosynthetics; and
- Functional flexibility.

The following are some of the advances that have been made and are being researched further in concrete.

- Admixtures to reduce the amount of water required in concrete mixes. This mix has a much higher strength and no reduction in workability.
- Admixtures to make concrete more resistant to salt corrosion in waterfront facilities and northern highways.
- High strength-to-weight polymer-impregnated fabrics and non-metallic woven fibers for sports facilities and temporary structures.
- Polymeric sprays that penetrate and harden in place.
- Coatings and linings for pipes and structural components.

An area of innovation that really requires attention is the replacement of steel cable used in:

- Suspension bridges;
- Prestressed concrete structures;
- Tunnel liners;
- Pipelines;
- Storage tanks; and
- Highway pavement foundations.

Other future needs in materials are (38):

- **Predictive models for construction materials and systems performance:** Standard organizations should establish standards for reporting and measuring construction data, focusing on developing consistent reporting formats and a coherent system of organizing information and predictive models that address clear objectives;
- **Materials life-cycle information system for construction facilities:** Worldwide public-private efforts should develop models and methods that identify and gather data needed for life-cycle analyses, assessment of materials and systems, and renewal assessments, through the collaboration of industries advanced in life-cycle methods, such as the chemical, electronics, and communications industries;
- **Client-oriented flexible engineering (COFE) to improve industry efficiency:** COFE involves integrated engineering design methods, information networks, and automated technologies applied to sustainable constructed systems. COFE should also realize the economic potential of automated and modular systems by adapting the principles and methods of information and automation technologies and flexible

manufacturing to sustainable constructed systems. The final phase of COFE would develop, deploy, and maintain commercial-scale networked knowledge systems for modular constructed systems;

- **International use of system modularity for constructed facilities:** Systems modularity is a set of units designed to be arranged or joined in a variety of ways and can ensure successful integration of building materials and systems which will in turn improve overall economics and quality. There should therefore, be a guide for using system modularity in design and construction, describing the design methodology and data protocols for design, manufacture and system integration. This whole process could be administered by an international steering committee, which could also be responsible for conducting an initial feasibility study;
- **Performance testing of materials and systems to reduce system costs:** A public-private consortium should be created to collect the data and conduct demonstrations, workshops, and training in the use and application of innovative designs and materials in large and full-scale testing and perform long-term monitoring of structures and facilities. This should result in the reduction of infrastructure costs due to more efficient design and construction practices;
- **Globally acceptable performance-based specifications for construction materials and systems:** Internationally accepted performance specifications need to be produced. This would require a consortium of international materials experts fluent in the performance approach to evaluate national construction projects employing the performance based approach. This data would then be synthesized into simulation models and knowledge bases for use by the design and construction industry decision makers. Enhanced predictive and assessment tools, simulations of new material development, knowledge bases, and better prediction methods of material durability and environmental degradation phase should result in improved uses of materials;
- **Training programs for life-cycle cost analysis:** Need to develop the tools and databases to support the evaluation of alternatives for materials, systems and construction operation approaches, and create training and education programs targeted at professionals. A global communication network to reach the professional community and public policy and opinion leaders as well as professionals, is also required. These objectives can be realized through a combination of symposia,

application of Internet communication capabilities, the development of model curricula, dissemination of existing databases and creation of new ones which would collect case histories of applications, and disseminate this information;

- **Discipline of renewal engineering:** There is an urgent need to develop a discipline (renewal engineering) in design and construction which would focus on design for renewal, renovation, and reuse. It would be based on demolition, renovation, recycling, life-cycle assessment, and the development of associated databases;
- **Cross-disciplinary and international research in renewal engineering:** Industry, with seed money from the government, should establish a data resource base on renewal technology development. To help with the expenses, the database could be operated and maintained by a private organization with subscriptions. This service would benefit the user and the industry by helping to focus research, enlisting new research, and advancing technology transfer;
- **Creating an incentive to reuse, renew, and recycle:** The industry should push for a combination of tax incentives and disincentives on construction materiel that would result in the market price of materials reflecting their societal values and true environmental costs. This would require an assessment of the materials market to determine the extent that recycling, renewal, and reuses is occurring. The assessment would include life-cycle cost analysis and data gathering to assist in the analysis for determining appropriate tax policy promoting the efficient use and reuse of materials; and
- **Life-cycle methodology tools for materials and systems:** A research and development effort is required to produce the needed models and methods for the construction industry, such as environmental life-cycle assessment models for inventory assessment, impact assessment, and impact evaluation.

10.4.7 Construction and Equipment

Construction represents over half of the U.S. annual capital investment and almost 10% of the GNP. However, productivity in construction is steadily declining and technology offers an important way to improve the performance of the construction industry.

Innovations are needed in construction and equipment technologies and practices in order to achieve sustainable development. These new practices will (36):

- Safely clean up hazardous sites;
- Improve worker safety;
- Increase worker productivity;
- Improve the quality of the constructed facilities; and
- Reduce facility delivery time.

The vision for the construction and building industries is (229):

- High quality constructed facilities;
- North American construction industry leads in quality and economy in the global market for construction products and services;
- The construction industry and constructed facilities are energy efficient, environmentally benign, safe, and healthy, and sustainable in use of resources; and
- Natural and man-made hazards do not cause disasters.

The future needs in construction and equipment are (38, 41 & 229):

- Communications and positioning systems, signal systems and satellites;
- Field construction technologies, including trenchless construction technologies, tunnels, soil improvements and stabilization, dredging technology, and rail track construction and rehabilitation;
- High-performance construction techniques such as improved information exchange, off-site prefabrication and resource scheduling;
- Construction waste disposal such as dredge spoil, characterization and assessment of contaminated sites and dry construction waste;
- Underground construction in automated tunneling, trenchless technology, hazards mitigation and construction effects on adjacent facilities;
- Construction safety;
- Rehabilitation and retrofit in system isolation and access to degraded segments;
- Decommissioning of temporary facilities and network devolution;
- Procurement and management practices in contracting practices and project management tools;
- Simulation and visualization;
- Computer-aided design;
- Computer-integrated construction;
- Advanced sensors;

- Construction robotics;
- Building automation systems (354);
- **Demonstration projects to encourage construction innovation:** Construction industry organizations should actively promote demonstration projects through recruiting projects, obtaining financing, developing risk-sharing mechanisms, and documenting and reporting on progress;
- **International dynamic project database for construction:** A project database should be developed consisting of 3-D design data, architectural schematics, engineering data, material selection criteria, vendor and manufacturing information, and other information that is needed for the useful life of a construction project. This would require an assessment of the current standards and capabilities, a definition of an open architecture that maintains flexibility, the development of a testbed for implementation, and the development of collaborative protocols with organizations with analogous situations;
- **Sharing of knowledge between developing and developed countries:** Need to develop construction and equipment strategies to help transfer infrastructure innovation to developing countries. First, the existing technologies that best meet the needs of developing countries, would have to identified, followed by conducting demonstration projects in cooperation with host countries. These results would be disseminated to the decision makers in both developing and developed countries ;
- **Decision support for eco-construction:** International effort would be required to develop a life-cycle framework that incorporates environmental impacts into the assessment of construction activities, through coordination among the construction industry associations and other interested bodies; and
- **Integrated sustainable project life-cycle management approach:** In order to reduce the lack of accountability among participants in the various project phases and corresponding suboptimization within the overall project, the construction industry needs to promote strategic alliances, rationalizing the regulatory and legislative structures, developing an overall government policy framework to encourage integration using government projects to set an example, shifting to performance-based specifications and standards, maximizing the use of information technologies,

developing appropriate incentive structures, and improving decision tools such as the use of life-cycle cost-benefit analysis.

10.4.8 Management

There is a great need for on-going research in the applications of data collection and management, process control, predictive modeling, and decision support analysis. Some areas of promise are (34):

- Computerized monitoring of the performance and condition of infrastructure.
- Knowing where infrastructure is located and how it was designed.
- Telecommunications such as traffic signal systems to link controls at intersections with one another and a central computer, route-guidance and geo-positioning systems and non-destructive evaluation techniques using sensors.
- Inter-personal communications using e-mail and message services.
- Improved video teleconferencing methods to reduce the problems faced due to intercity and interurban mobility.

Other potential areas of research related to the management of infrastructure are (38, 41 & 229):

- Integrated databases and information systems;
- Knowledge systems (successors to standards and books);
- Integrated project information systems;
- Construction management technologies;
- Collaborative decision-making environments;
- Postoccupancy evaluation systems;
- Computer-aided facilities management;
- Analytical inventories of infrastructure systems;
- Statistical analyses and benchmarking of infrastructure;
- Deviation-detection systems for public health and safety;
- Quicker response infrastructure management;
- Infrastructure junction points and common-use corridors;
- Private and public interface in infrastructure;
- Systemwide condition assessment;

- Information and decision systems, including maintenance management information systems, geographic information systems, artificial intelligence, and simulation models;
- Advanced data-acquisition and management methods such as the remote satellite imagery;
- Education of infrastructure management such as using information highways uses of multimedia.
- **Needs assessment:** The true condition of North America's Infrastructure needs to be known in order to make investment and rehabilitation decisions. Since current assessment data are highly fragmented, databases should be created to pull all this information together. In addition, there are major gaps in the information available requiring further studies and surveys to be conducted. A complete inventory of North America's infrastructure and its total worth would also be very beneficial.
- **Condition assessment:** Research needs to be undertaken to recommend measures for assessing structural integrity, adequacy of capacity, quality of service, and facility role. In addition, facility deterioration rates under varying conditions and the appropriate criteria for measuring and monitoring facility conditions over time should also be examined. Other research needed are nondisruptive, nondestructive condition-monitoring techniques such as structural assessment and site characterization, environmental factors and management of residuals of chemical grouting, and management of infrastructure waste and residuals;
- **Information systems in condition assessment:** Experiences of federal, state/provincial, and local agencies in the use of information systems in infrastructure management should be analyzed. Are they using the full potential of these technologies?
- **Risk analysis in infrastructure decision making:** Are risk analysis methodologies being used in decision making, and , if not, what are their potential benefits in determining conditions and evaluating options?
- **Life-cycle cost analysis:** Research is need to determine the most appropriate repair, rehabilitation, and maintenance strategies for infrastructure facilities and the different maintenance options available for the different facilities;

- **Methods for evaluation benefits and costs:** More information is needed on the benefits and costs of various levels of system conditions and performance and the trade-offs involved in maintaining different levels of service;
- **Developing risk guidelines for construction industry stakeholders:** More in depth knowledge is required for the application of risk assessment in the design and construction of facilities. This could be achieved by the development of an information technology-hazards database for different types of construction. The database should incorporate existing risk analysis methods and techniques, case studies, and success stories, and updated regularly;
- **Establishing consensus construction goals:** The several stakeholders of a construction project usually have different goals in mind, particularly in the case of international projects. It would therefore be very beneficial for the key stakeholders in the development and operation of facilities to identify goal-setting processes and benchmark high-performance strategies in the form of reports and handbooks that could be used by others;
- **Updated and streamlined construction contracts:** Due to the current standard conditions of contracts, contract forms are not reflective of current practice and can impede innovation. They are at times unilaterally modified, resulting in adversarial conditions, claims and litigation. Therefore, organizations involved in the preparation of such standard contract documents must collaborate to find solutions to the problem of inadequate standard conditions;
- **Establish affordable sustainable construction objectives:** It is important to define the cost of achieving sustainability by developing a framework for allocating costs and benefits, methods for observing these values, and preparing a report on the implication of design, construction, materials, operations, and human resources. A model for conducting cost-benefit analyses involving sustainability would be an ideal outcome of this research. These models should include examples and case studies, an electronic tutorial on the Internet, and applications across the various projects in the public and private sectors;
- **Information on avoiding adversarial relationships:** There is a need for manuals of best practices for the administration and management of contracts on the problems and solutions for dealing with adversarial relationships in the construction process;

- **Incorporate performance criteria into the design and construction process:** Performance criteria for specifying and evaluating qualities of construction products and systems should not restrict the design and construction industry innovation. The current performance practices in the construction industry should produce standards and codes for testing, develop manuals and testing mechanisms for approval of nonstandard products, and model procurement systems and construction documents for performance concept implementation;
- **Develop virtual project delivery system:** New information technology based "virtual" delivery systems can lead to cost reduction, increased productivity, improved quality, and efficiency. They would require global inventory of existing systems, develop global standards, identify risk management issues, and common educational curricula; and
- **Seamless knowledge transfer in construction:** Accessible databases need to be created by taking an inventory of existing efforts, the development of information transfer protocols, the bringing together of key stakeholders in the design and construction industry.

10.4.9 Financing

Since financing infrastructure construction and rehabilitation is a major concern and one of the major causes leading to the current infrastructure crisis, it is crucial that we finding new ways to finance infrastructure development and renewal. Some future needs are (210):

- **User fees:** There is little empirical analysis of the impact of charging for the amount of waste generated, illegal dumping, and the need for landfill sites. Municipalities are interested in how to estimate the cost of water and how to set the fee. Price elasticities for different users also needs to be determined. In addition, there is little Canadian empirical work on the impact of tolls on traffic and the needs for roads;
- **Development charges:** Although there is extensive literature on development charges in the US, it mainly focuses on who bears the burden of the charge. Little has been written about the impact of the charge on the amount of development, the timing go development, and urban form and density;

- **Land value capture taxes:** The empirical question that needs to be studied relates to how to isolate the increase in land value attributable to the public investment from other variables which influence land values;
- **Public-private partnerships:** It is important to find out what kind of cost savings can be gained for the private and public sector. What are the reasons for cost savings? An empirical study of the impact of privatization on cost, quality of service, employment and other factors would also be useful information for municipal officials; and
- **Borrowing:** There is no Canadian study available to explain the reasons for differences in borrowing practices by municipalities, to explain why some of them do not borrow and what factors might help reverse this trend.
- **Infrastructure Banks:** Research should be done on banks created for the sole purpose of financing infrastructure. Since there is no such institution in Canada, it would be beneficial to have research outlining a framework for such a bank and how it could be financed and operated.

10.4.10 Standards, Regulations and Other External Influences

There are numerous external forces that affect the innovation in the design and construction industry. Research and measures need to be undertaken to ease innovation and limit the forces that harm this process. Therefore, research needs to be undertaken in the following areas (38, 41, 79 & 229):

- Technology management, including project design, procurement options, standards and specifications, risk and reliability, proprietary technologies, and personnel training, education and recruitment;
- Performance standards for products and processes;
- Conformance assessment system;
- Certification system;
- Removing institutional barriers to innovation;
- Impact of procurement methods;
- Performance/cost trade-offs under uncertainty;
- Institutional obstacles to innovation such as criteria and standards;
- Research on innovation processes;

- **Establish international standards of conduct and ethics:** An ethics council can be established to develop standards of professional conduct to review, determine, and sanction violations, and to assist in ensuring that society is adequately protected as industry seeks new and innovative approaches. The council would serve as a professional watchdog to help ensure that all parties are treated equitably. Information would need to be collected on the various issues involved, including a review the systems in the various countries and an assessment of benefits and costs;
- **Global construction forum to advance innovation:** In order to improve current construction practices, a uniform and open system to share and advance infrastructure technologies should be established. A global forum through the coordinated efforts of international organizations would facilitate information on innovation, support each other's recognition of innovation, disseminate results and track the commercialization of innovative technologies;
- **Examine and coordinate codes, standards, and regulations internationally:** Need to develop an approach to allow greater use of appropriate materials and products, faster review of innovative technologies and systems, and greater global cooperation, to achieve innovation, cost savings, and productivity improvements. This would require the development of international teaming arrangements among codes and standards organizations, international agreements among testing organizations, universities, standards organizations, user organizations, and the promotion of performance-based standards;
- **Take a leadership role in defining sustainable solutions:** Public opinion leaders and policy makers need to be better informed on the issues and consequences of their actions through a broad context of issues across a variety of mass and targeted media The information would have to be multidisciplinary and include case studies of success stories to highlight the benefits;
- **Form an international information-access system through collective actions:** Government, industry, and academia should enter into an international agreement (a multilateral memorandum of understanding) that would further develop the international linkages and collaborations, inventory and access existing activities and resources, define new delivery mechanisms, identify additional resources required, and implement new centers and activities that may be required;

- **Role of standards:** What are the technical, economic, and legal implications of the standards put in place by professional associations, trade groups, and the federal government. What are the costs of additional standards or regulations on infrastructure decisions?
- **A national organization dealing with infrastructure needs:** There is an urgent need for an organization devoted to the needs of the infrastructure. Currently some of the needs are met by several organizations such as the FCM, ASCE, CERF, APWA and NACO; and
- A national infrastructure policy.

10.5 SUMMARY

It is now clear that our infrastructure is in a crisis. It must be maintained if we are to compete in the global economy and maintain our standard of living. This can be achieved if we avail new technologies and encourage further research and development in infrastructure technology. The adoption of new and appropriate technologies will not only improve the infrastructure efficiency but will also reduce the cost of new construction.

Innovation in infrastructure influences all aspects of the systems of infrastructure. For instance, faster and more economical transport has led to suburbanization and spread of urban areas, leading to increased demand for extensive infrastructure such as water supplies. Increased development causes traffic congestion and increasing demand for better transportation, thereby generating a vicious cycle.

Plenty of opportunities exist in the research and innovation of infrastructure in areas such as solid waste management, transportation and materials technology. However, there are several barriers that have to be overcome if we are to proceed with research and innovation. Some of these barriers are industry fragmentation, risk and reliability, and standards and regulations. In addition, the high capital cost and typically long service lives of infrastructure facilities (30-70 years and more) make the spread of technological innovation a slow process, as compared with the automobile industry (152).

We should be spending more on infrastructure research and innovation and accelerating the transfer of research results into practical improvements in infrastructure. By strengthening R&D and innovation, we are very likely to see higher productivity, creation of wealth, sustainable development, and improvement in the standard of living.

As Bernstein pointed out, government, industry, academia, and the professions need to be united to meet the infrastructure needs of the 21st century. This can only be achieved by establishing specific and quantifiable goals, identifying new construction research and development needs, developing an improved life-cycle process, obtaining consensus on technology policy issues, and introducing advanced design practices, high performance construction materials and systems, and the latest equipment to improve the quality in engineering and construction practices (50).

11.0 WHERE DO WE GO FROM HERE? ROLE OF THE CIVIL ENGINEER AND EDUCATION

11.1 INTRODUCTION

The civil engineer has played an important role in designing the infrastructure and can play an even more important role in maintaining and preserving it. Although the infrastructure problem is formidable, civil engineers can help solve the problem by fulfilling their roles well and adopting some new ones such as politics.

Unfortunately many civil engineers are still not totally aware of the infrastructure crisis or the application of sustainable development to their discipline. Some realize the significance of the infrastructure problem, but they do not realize what can be done about rectifying the situation. Every civil engineer needs to play an active part in solving the infrastructure problem and in promoting and practicing the principles of sustainable development.

11.2 ROLE OF THE CIVIL ENGINEER IN INFRASTRUCTURE RENEWAL

The importance of maintaining the infrastructure needs to be stressed constantly by civil engineers who know too well that without periodic maintenance, many facilities will not last their entire design life. They can prove the value of preventive maintenance through economic analysis. They need to point out that much of the maintenance needed now is the result of earlier neglected or deferred maintenance and that liability is a major cost to consider.

In order to better understand the role of the civil engineer, we need to consider the following definition from the American Heritage Dictionary: "Engineering-the application of mathematics and scientific principles to practical ends such as the design, construction, and operation of efficient and economical structures, equipment, and systems."

Discovering engineering problems is a basic part of a civil engineer's job. Finding a problem before it occurs can lead to preventive measures before it is too late. Civil engineers have an important role to play in accurately assessing the true infrastructure needs. This applies to the First Fundamental Principle of the ASCE Code of Ethics, which states that engineers use "their knowledge and skill for the enhancement of human welfare." However, many engineers feel no need to publicize the problem. Problems need to be announced to make the public and the politicians more aware of the current situation.

Perhaps if there always had been awareness of the problem, the money spent on public works would not have decreased over time.

Civil engineers also need to be diligent in finding infrastructure problems. This applies to the Second Fundamental Principle of the ASCE Code of Ethics, which states that engineers shall serve "with fidelity the public, their employers, and clients." In New York City, not many worry about the city's two giant water tunnels which have not been inspected since construction. If either were to have a problem, it would result in a major crisis.

Engineers are responsible for providing safe, economic, and efficient solutions to problems. Today, budgets are very limited and every bit saved can help. For instance, engineering improvements on roads and bridges can prevent injuries, save lives, and money (135).

Civil engineers must use their creativity when analyzing problems and determining solutions. While many American engineers have shown great creativity in the past by designing tunnels, subways, bridges before cars were invented, etc., today, when confronted with many pages of standards and codes, they often feel that there is no room for creativity. Many try to pick designs out of codes, feeling that everything is specified. Following the accepted method can discourage new methods and technologies from being tried out. Being creative and using new procedures and technologies will help the civil engineering profession grow and at the same time improve the economy and efficiency of many operations (135).

Finally, civil engineers need to work hard at bringing together representatives from industry, academia, and government, to create a new generation of infrastructure needed for the 21st century and improve the business performance of the construction industry (23).

Demands on municipal administrators are increasing over time due to the limited sources available to manage infrastructure facilities. They need to make proper decisions about resource allocation to correct deficiencies (12), and must ensure that cut-backs in urban services are both equitable and reasonable and keep in mind that savings today may mean increased deterioration of existing facilities and greater maintenance costs tomorrow (111).

A group of graduating engineers were told to expect the following (111):

> *"You will probably spend more time dealing with government than with other engineers.... You will appear before committees and commissions seeking the right and permission to build, to design and to enlarge the national horizons. Then you will appear before*

them to explain why you did what you did, even though you had permission to do what you did."

Problems are becoming more and more complex requiring permitting processes, legal issues, labor relations, financing, and more comprehensive studies. It is therefore essential that civil engineers recognize the importance of becoming leaders of a professional team by being able to assemble various areas of expertise, such as chemical engineering, mechanical engineering, agricultural engineering, architecture, hydrology, ecology, etc., manage and monitor them for overall quality and performance (181).

Due to the complexity of municipal infrastructure, any solution envisioned by civil engineers must concurrently resolve social, economic, environmental, legal, and political issues, as well as technological ones. Disruption to neighborhoods and businesses, the long-term impact of projects on neighborhoods, and the effects on the natural environment must all be taken into account when working on a civil engineering project (24).

Functioning within our increasingly complex public/private system requires negotiating skills, managerial talents, political astuteness, communications skills and the ability to interpret the law. New graduate engineers will discover that the technical expertise they acquired at the university constitute only a small portion of the skills needed to function within public organizations. To work for the public sector, they need to be aware of their role as a political advisor to elected officials and as implementers of their policies. Therefore, engineering students must be taught the political and bureaucratic processes operating within our society (111).

11.3 ROLE OF CIVIL ENGINEER IN SUSTAINABLE DEVLEOPMENT

In order to implement new technologies, education and training is needed for designers, manufacturers and fabricators, regulators, construction workforce, operators, maintenance workers, and users. Educational curricula will be required for each new area of technology and each category of users (229).

Engineers have a very important role in guiding the society along a sustainable path. They are after all major contributors to the present quality of life that we enjoy and at the same time share the blame for the present degraded state of the planet. They must now stop contributing any further damage to the state of the planet and try to solve what has already been damaged. Therefore, their future role should be the prevention of any damage to our environment and natural resources. It is time for the engineers to realize that not all problems can be solved by technical solutions and to inform other professionals and the general public that they too have a major role to play in assuring a sustainable future. They need to become advocates of public debates on policy development, planning and engineering implementation stage of any project, rather than just being mere participants.

Engineers have the know-how of applied technology, and they should pass it on to other individuals and educate them on how to apply it to attain the principles of sustainability. They should warn their clients and the general public about the consequences of taking non-sustainable courses of action and they must emphasize the importance of applying the principles of sustainability in the planning, design and construction phases of all projects.

In the past and in most cases today, engineers practiced their profession with safety as their primary goal. However in the future, not only will they have to design projects that are safe, they will also have to design projects that are sustainable. Sustainability will therefore become an additional ethical component.

Engineers of the future, will have to deal with defining the problems, management of pollution, and sustainable development. Before engineers posed the question **How?** In the future they will also have to pose the question **Why?** Should something be done or not? Will it be reusable?

Whenever possible, engineers should consider redevelopment, retrofit, revitalization, rehabilitation and repair, rather than development, when undertaking new projects. Engineers are required to work with many other outside influences and other professionals such as economists, sociologists, etc.

The Canadian Society for Civil Engineers (CSCE) guidelines for civil engineering practice with a commitment to a sustainable future are (137):

1. *"Civil Engineers need to develop and promote a sustainability ethic.*
2. *Civil Engineers need to recognize the interdisciplinary nature of engineering.*
3. *Civil Engineers should practice engineering in accordance with an ethic that leads to sustainable development.*
4. *Civil Engineers should act ethically, with integrity and objectivity, remembering their responsibility to the community.*
5. *Civil Engineers should pursue and encourage a sustainability ethic in their professional development."*

Johnson and Kramer outline the principles for a sustainable future as the following (137):

Anticipation and Prevention:

- Avoids environmental degradation and considers conservation at all planning and development stages.

Full Cost Accounting:	• Takes into account the environmental and social costs along with the regular market costs.
Informed Decision Making:	• Considers long-term planning and gains and includes effective public participation.
Living off the Interest:	• Treats natural resources as something that is to be replaced as it is depleted.
Quality of Development Over Quantity:	• Focus is shifted to emphasize product durability, energy efficiency and recycling.
Respect for Nature and the Rights of Future Generations:	• Quality of life considerations must be taken into account in all decision making processes.

According to the International Federation of Consulting Engineers (FIDIC), the role of the engineer should result in (89):

- Careful evaluation of the environmental benefits and adverse impact of proposed projects
- Conservation of energy
- Reduction in the use of non-renewable resources and increased re-use of materials
- Reduced waste production through improved industrial processes, better transportation and distribution systems, and recycling of waste products
- Sound agricultural and other land-management practices
- Restoration or improvement of damaged land, polluted water supplies and disturbed ecosystems
- Effective transfer of environmental knowledge and experience

Ethics and responsibilities

Observing a code of conduct is a fundamental part of the profession of a consulting engineer. FIDIC states that the goals of consulting engineers should include a commitment to achieve sustainable development and they should give the highest priority to the short term and long term welfare, health and safety of the community. Consulting engineers should consider regional, global and cumulative effects of projects in addition to local effects (89).

FIDIC recommends that each consulting engineer should (89):

- Keep informed on global environmental trends and issues
- Discuss environmental problems with professionals from other disciplines
- Provide information to clients, the public and government about environmental problems and how adverse effects can be minimized
- Become involved in organizational activities, including assistance to governmental authorities, that promote the protection of the environment
- Encourage and promote appropriate environmental laws and regulations
- Actively support and participate in all forms of environmental education
- Promote research and development relevant to protecting and improving the environment.

Project actions

FIDIC recommends that consulting engineers should (89):

- Recommend that environmental studies be performed as part of all relevant projects. Such studies will normally require a multidisciplinary approach.
- Evaluate the positive and negative environmental impacts of each project. This evaluation might be based on a preliminary review of available information, or on the engineer's experience. They should evaluate the basic functions and purposes behind a project. They should suggest alternatives to their clients if environmental risks emerge.
- Develop improved approaches to environmental studies. Environmental effects should be considered early in the planning process. Studies should evaluate the long term consequences of environmental changes.
- Make clients aware that engineers can reduce but not always eliminate adverse environmental impacts. The legal and financial responsibilities of all parties should be clearly defined.
- Urge clients to prevent or minimize the adverse environmental effects of projects in all phases -- initial planning, design, construction, commissioning, operating and decommissioning.

- Finally, take appropriate action, or even decline to be associated with a project, if the client is unwilling to support adequate efforts to evaluate the environmental issues, or to mitigate environmental problems.

11.3.1 The Rio Declaration - Some Implications for Engineering (237)

Civil engineers should study and reinterpret the Rio Declaration (see section 3.4) into engineering related guidelines.

Agenda 21

- The precautionary principle should be understood and applied.
- All engineers should be fluent in environmental impact assessment and use it as a tool for selection of technical options.
- Develop education and training programs that enhance the capacity of the engineering profession to contribute to 'Agenda 21' outcomes.
- Foster the transfer of technical information, particularly for the assistance of developing countries.
- Develop the understanding of, and the facility and techniques for the integration of technology into the social, environmental, and cultural context.

The Convention on Biodiversity

- Note that conservation of the productive capacity of ecosystem, is fundamental to sustainable development, and review all engineering practices in this light.
- Ensure that all engineers receive general education about ecosystems, earth systems, and the Convention on Biodiversity.
- Contribute to the development and monitoring of national strategies, plans and programs for conservation and sustainable use of Biodiversity.

The Convention on Climate Change

- Promote research in and implementation of energy efficient policies, technologies, and practices.
- Promote research in and implementation of technologies that eliminate or reduce emissions of greenhouse gases, particularly in relation to energy, transportation, industry, and waste disposal.
- Promote research into and application of sustainable energy technologies; e.g. hydro, solar, wind and tidal sources of energy.
- Participate in and contribute to the development and monitoring of national policies related to climate change.
- Foster the transfer of information about mitigating technology, especially to developing countries.
- Consider and allow for the risks of rising sea level in relation to low lying areas, and the need for additional warning and protection against storm events.

11.3.2 Action Principles for the Engineering Profession

The Challenge

According to the American Association of Engineering Societies (AAES), environment, technology, and economic development need to be seen as interdependent concepts in which industrial competitiveness and ecological sustainability will be addressed together as complementary aspects of a common goal. Engineers, as agents for the implementation of change, along with other professionals need to be adaptable to this changing environment. Engineers must become "facilitators of sustainable development", through the information they provide, the decisions that they make, and those that they influence.

Engineers must assume a more assertive and proactive role in defining and shaping a desirable future. They must be ready to answer hard questions such as:

- What new tools and processes must be developed?
- What must we do as individuals and organizations to achieve these developments?

- How should we set priorities for this work?

If they do not meet this challenge, they will be left behind in the decision making process that will influence the future shape of this world. Engineering for a sustainable future will require engineers to engage more actively in political, economic, technical and social discussions and processes to help set a new direction for the world and its development (1).

Sustainable Technologies

The creation of sustainable technologies and processes is critical in achieving the sustainable integration of the environment and technology in the foreseeable future. Technology focused on sustainable development can help solve problems created in the past and prevent new ones from arising in the future. Engineers must work with others to adapt existing technologies and create and disseminate new technologies that will facilitate the practice of sustainable engineering and meet societal needs (1).

Design Concepts

In accepting the challenge of sustainable development, Hatch suggests the following of eight design concepts for building the foundations and the framework for sustainable engineering (116):

1. Education

As facilitators of sustainable development, engineers must have the skills, knowledge, and information required to achieve a sustainable future. Therefore, we must remedy the deficiencies in their education. Integrating the concepts of sustainable development demands that engineers have a solid understanding of the environmental and economic issues, problems, and, especially risks and potential impacts of every action.

Engineers must also continuously educate those they serve and strive to educate all elements of society and promote universal adoption of a sustainable development ethic. The engineering profession as a whole must assume a responsibility for educating not only those current decision makers, but also future engineers and future decision makers.

2. Adopt the Notion of "Ecosystems" Thinking

Engineers are traditionally taught problem-solving skills that break down each problem into its simplest pieces, study each of them, and then move on to the next in a linear manner. For them to approach sustainable development in a manner that imitates the natural processes around us, engineering must become a unifying, not a partitioning discipline.

3. **Emphasize the Aggregate Consequences of What Engineers are Recommending**

Practicing "ecosystems" thinking requires that engineers begin to examine more carefully the aggregate long-term consequences of a decision, in terms of both time and space by understanding the net contribution of individual impacts or decisions.

4. **Acquire Environmental Economic Tools to Integrate the Environment and Social Conditions into Market Economics**

A market economy based on a free enterprise system affords the best opportunity to achieve that level of global economic development that must occur to support growing populations and sustainable development. Therefore, engineers must develop and practice "environmental economics."

5. **Search for Sustainable Alternatives**

Engineers typically take a narrow and circumscribed approach and usually fail to come up with environmentally sustainable alternatives. Therefore, the engineer as a project team leader or member bears much of the responsibility for recommending the technical alternatives. They need to talk to their clients, or to the public and private decision makers and tell them that their idea or project is not sustainable, explain to them why, and offer them alternatives. After all, the choices that are made to determine whether the project ends up creating problems or solutions. Life-cycle consequences run along the project's entire time dimension, from planning through design, construction, operation, deactivation, demolition, and even disposal.

6. **Develop and Apply Technology to Serve Sustainability**

We need new technologies, from materials to processes that we have not even thought of yet. Technology focused on sustainable development is a key to solving problems created in the past and preventing new ones in the future.

7. **Listen to Those We Serve**

Engineers must consider sustainable development as a dynamic process that responds to the continuously changing needs and knowledge base of the society, culture, and community they serve. It is common practice for engineers to become so caught up in the wonders of the short-term creation of "things" that they forget the long-term and enduring effects on the people we are really serving.

8. **Cultivate a Multidisciplinary Team Approach**

A multidisciplinary approach in sustainable development needs to go well beyond getting the civil, electrical and the mechanical engineers together. It is crucial to bring together the knowledge, skills, and insights of physical as well as social sciences.

11.3.3 Environmental Principles For Engineers

The Institution of Engineers-Australia has defined a set of environmental principles for engineering practice. These principles complement the Code of Ethics and incorporate the concept of ecologically sustainable development, and the practice generally of environmentally responsible engineering. Topics include ethics, sustainable development, environmental impact assessment, environmental economics, community participation and considerations for the practice of engineering internationally. Statements and policies from the World Federation of Engineering Organizations **(WFEO)**, and the International Federation of Consulting Engineers **(FIDIC)** have also been incorporated in part in the following principles (130).

1. Engineers Need to Develop and Promote a Sustainability Ethic, and:
   - Recognize that ecosystem interdependence and diversity form the basis for our continued existence.
   - Recognize the finite capacity of the environment to assimilate human made changes.
   - Recognize the rights of future generations. No generation should increase its wealth to the detriment of others.
   - Promote a clear understanding of the actions required in engineering practice to improve, sustain, and restore the environment.
   - Promote the development of alternatives to the use of non-renewable resources.

- Promote the wise use of non-renewable resources through waste minimization and recycling, wherever possible, in engineering activities.
- Strive to achieve the beneficial objectives of engineering work with the lowest possible consumption of raw materials and energy, and by adopting sustainable management practices.

2. Engineers Need to Recognize the Interdisciplinary Nature of Engineering, and:
   - Recognize that the expertise required for carrying out a specific engineering activity may not be sufficient for judging the environmental implications of that activity.
   - Involve other environmentally-based disciplines in determining the environmental implications of engineering activities.
   - Recognize individual limitations in assessing environmental effects, and respect other professional opinions.
3. Engineers Should Practice Engineering in Accord with a Sustainability Ethic that leads to Sustainable Development, and:
   - Study thoroughly the environment that will be affected, assess all the impacts that may arise, and select the best alternative for an environmentally sound and sustainable project.
   - Urge clients or employers to incorporate environmental objectives into design criteria, and to prevent or minimize the adverse environmental effects of engineering activities.
   - Include consideration of environmental effects at all phases of planning and implementation of engineering activities.
   - Consider the consequences of all proposals and actions, direct or indirect, immediate or long term, upon cultural heritage, social stability, health of people, and equity.
   - Identify and act to minimize potential environmental effects of engineering activities.
   - Rigorously examine the basic functions and purposes behind a project to recognize options and alternatives to improve sustainability.
   - Inform clients that engineers can reduce but not always eliminate adverse environmental impacts without incurring increased costs. This does not imply that increasing the cost will solve all environmental problems.
   - Suggest alternatives to clients if the proposed engineering activity is likely to create unavoidable environmental risks.
   - Urge clients to incorporate monitoring of environmental change into projects, and to adjust operations as a result of monitoring.

- Include costs and benefits relating to the environmental quality and degradation in economic evaluations of engineering activities.
- Recognize the rights of the community to be involved in project formulation and development and actively encourage such involvement.

4. Engineers should Act with Integrity, Objectively and Ethically, remembering their Responsibility to the Community, and:
   - Recognize all actual, potential or perceived conflicts of interest in relation to engineering activities.
   - Recognize that compromising environmental quality or standards in engineering activities is an appropriate means of reducing cost. This approach may only achieve short term gains at the expense of long term sustainability.
   - Provide information to clients, employers, the public and government about ways of improving the sustainability of engineering activities.
   - Disclose environmental implications and external costs of engineering activities, taking into account the often inadequate and uncertain nature of environmental data.
   - Report on environmental issues with honesty and integrity.
   - Decline to be associated with engineering activities if the client or employer is unwilling to support adequate efforts to evaluate environmental issues or to mitigate environmental problems.
5. Engineers Should Pursue and Encourage Professional Development, and:
   - Keep informed on global environmental trends and issues.
   - Actively support and participate in environmental education.
   - Maintain dialogue about sustainable development with other professions.
   - Learn the skills necessary to develop active community participation in engineering activities.
   - Assist and advise other engineers where necessary in the application and use of the principles of sustainable development identified in this document.

11.3.4 Code of Environmental Ethics For Engineers

The World Federation of Engineering Organizations (WFEO) is the largest global engineering organization representing more than 80 countries and 10 million engineers. Its Committee on Engineering and the Environment states the following principles (226):

- Try with the best of your ability, courage, enthusiasm and dedication to obtain a superior technical achievement, which will contribute to and promote a healthy and agreeable surrounding for all men, in open spaces as well as indoors;
- Strive to accomplish the beneficial objectives of your work with the lowest possible consumption of raw materials and energy and the lowest production of wastes and any kind of pollution;
- Discuss in particular the consequences of your proposals and actions, direct or indirect, immediate or long term, upon the health of people, social equity and the local system of values;
- Study thoroughly the environment that will be affected, assess all the impacts that might arise and select the best alternative for an environmentally sound and sustainable development;
- Promote a clear understanding of the actions required to restore and, if possible, to improve the environment that may be disturbed, and include them in your proposals;
- Reject any kind of commitment that involves unfair damages for human surroundings and nature, and negotiate the best possible social and political solution; and
- Be aware that the principles of ecosystemic interdependence, diversity maintenance, resource recovery, and interrelational harmony form the basis of our continued existence and that each of those bases poses a threshold of sustainability that should not be exceeded.

The General Assembly of the WFEO recommends that each of its National Member take the following steps to implement the engineering contribution to the global plan of action of Agenda 21, and the Declaration of Sustainable Development made by the 1991 WFEO General Assembly (226):

- Establish a code of ethics which recognizes the new responsibilities of engineers for sustainable development;
- Promote the inclusion of principles and practice of sustainable development in the curriculum of engineering education and training;
- Establish a national committee on engineering and the environment as a focus for the development of policies on the role of engineers in sustainable development;
- Support and promote the establishment of centers for sustainable development and environmentally sustainable technologies linked together in a national network for the exchange of information and research;

- Seek to incorporate national engineering institutions, including universities, research institutes, professional societies, and academics of engineering, in the national network; and
- Support and promote the establishment of regional centers and networks for sustainable development, and ask the WFEO Committee on Engineering and the Environment to generate information that will assist national members.

11.4 CIVIL ENGINEER AS POLICY MAKER

As stated earlier, the blame for the infrastructure crisis does not lie just with the politicians, but also with the civil engineer. Civil engineers have failed to educate the politicians and let them make policies and important decisions on infrastructure. The role of the civil engineer has gone through many changes over time, from that of a bench engineer to that of project manager to that of coowner and financier. It is now time to take the next step to policy maker. So far, we have allowed other professionals such as lawyers and politicians make important decisions on urban transportation, toxic emissions, housing crisis, etc., who do not have the same education base in science and technology as civil engineering do.

Although the design and construction industry accounts for a major portion of the North American total domestic product (GDP), the leadership of civil engineers lacks the cohesive force needed to influence policy and direction as the leaders of the automobile or electronics industry do. This is largely due to the fact that the design and construction industry has over a million firms, most of which are small firms employing fewer than 10 employees (23).

In the past, a majority of those heading transportation, highway and public works departments were all civil engineers, but now, these same posts are held mostly by non-engineers. Engineers should occupy policy making governments posts in which their engineering expertise could be of great use and take a more active role in the debate on budget problems at all levels of government (12).

Since most public works are administered through some form of government, the engineer is required to enter the political arena. Therefore, according to Jessen, the role of the civil engineer in solving America's infrastructure problem includes (135):

- Discovering and announcing engineering problems and solutions;
- Being creative;
- Stressing the importance of maintenance;
- Reevaluating current engineering standards; and

- Getting involved politically.

More engineers in the political arena would have the most effect upon the progress of the infrastructure solution. There are two reasons for which civil engineers need to get involved in politics; The majority of public works are funded in some part by governments, and those that are not, fall under some government regulations. If an engineer were in office, he or she would not take the infrastructure for granted, as it is today, and would probably consider supporting public works more than most people. This is important since one of the major causes of the infrastructure crisis is political inaction and finding the funds for repair. Even though the cost of repairing the infrastructure is too large, the engineer would less likely be intimidated by the total cost, and could logically set priorities for the available funds and be less likely to neglect maintenance to save money.

Civil engineers need to ensure that the current regulations concerning engineering standards are practical, or even necessary. These standards need to be reevaluated and use current, not outdated data. For instance, many facilities are retired based upon their expected service life, rather than a mix of several factors. In addition, there are simply too many regulations in place making it very frustrating for the practicing engineers.

The content and volume of the current regulations pose a great problems for engineers. However, in many cases, regulations can only be changed through the political process. This should be a great incentive for engineers to get involved in politics and try to make regulations more realistic and workable (135).

The role of the engineer is very important in promoting sustainable development in the engineering and construction field. However, the individual engineer has done little to influence public and government policy on sustainable development. Engineers can, and should make a unique contribution to the environmental policies since they have relevant technological skills, ability and experience with thinking through complex issues.

The engineering profession can contribute to environmental policy in some of the following ways (36):

- Lobbying of elected government officials, staff and government agencies by professional bodies to encourage governments actions in procurement, contracting, executive orders, legislation, regulation and demonstration projects to act as incentives, demonstrate benefits and serve as models for sustainable development;
- National professional societies can develop and implement programs for training and educating engineers on ways of participating in public policy decisions and develop a

list of experts in particular areas who are called to give testimony before government bodies;

- Developing consistent, uniform model codes, performance standards, and guides taking environmental issues into account;
- Serve to clarify and stabilize markets for sustainable materials, products, processes and services;
- Developing a database that would act as a source of information for environmental technology and cost information for a variety of alternative options. It would serve and promote sustainable development for engineers, consumers and decision makers;
- Promoting curriculum development and course offerings in green technologies for engineering schools, and promoting professional education and training in these new technologies;
- Preparing and disseminating case studies as an aid to public education;
- Preparing of objective guides for local decision makers;
- Exchange data on a worldwide basis on how sustainable technologies work in economic, social, political and technical terms;
- Contribute to public debate through professional bodies and personal networks and becoming more involved in providing leadership and technical input for upgrading local codes and standards;
- Develop expertise in environmental engineering and awareness of sustainability issues;
- Seek out leadership positions as congressional/legislative resources for engineering and construction related legislation; and
- Develop methods of establishing practical managerial frameworks within engineering organizations to promote sustainability, etc.

11.5 ROLE OF ORGANIZATIONS

Existing and new organizations should take on the challenge of infrastructure renewal and its sustainable development. Local, national, and international engineering societies and associations have the potential to reach all the practicing engineers worldwide. There is a need to develop a process to network professional societies and associations to share information on sustainable development in practice, education and research. Sustainable organizations should be promoted and the business community made more aware of how the sustainable approach yields a positive financial picture in the long run.

Existing professional societies and associations should develop international agreements among engineers and to bring to worldwide attention the potential adverse environmental effects of hazardous waste and systems. They should address the development and implementation of sustainable development principles in engineering and construction. A task group could be established to identify and contact all groups that have or should have an interest in sustainability as it applies to civil engineering. This task committee could then establish permanent joint committees to carry on the collaborative work (38).

The Civil Engineering Research Foundation (CERF)

CERF is an independent non-profit organization that serves as "facilitator, coordinator, and integrator" of civil engineering research for the entire profession. It was created by the American Society of Civil Engineers (ASCE) and places special emphasis on the revitalization of the public works infrastructure and improvements in the competitiveness and business performance of civil engineering in the design and construction environment. It was also mandated to enhance environmental quality and advance the civil engineering profession through innovation in emerging technology areas such as construction automation, new materials, space structures, and others (2).

American Association of Engineering Societies (AAES)

The AAES member organizations represent more than 700,000 engineers in the mainstream of engineering design, construction, management, research and education in the United States. AAES is working with and through the World Engineering Partnership for Sustainable Development (WEPSD), to promote public recognition and understanding of the needs for sustainable development, and the policies and technology required to achieve a sustainable world for future generations (1).

World Engineering Partnership for Sustainable Development (WEPSD)

The WEPSD is a global coalition of engineering organizations committed to long-term actions in support of sustainable development. It is an interdisciplinary partnership between the international engineering, applied science, and business communities, dedicated to unifying the world engineering community to encourage sustainable development practices. It functions as a non-profit organization whose member associations include engineers from industry, private practice, universities, environmental non-governmental organizations, governments, and multilateral groups. It was formed in 1992 through the combined efforts of the World Federation of Engineering Organizations (WFEO), the International Federation of Consulting Engineers (FIDIC), and the International Union of Technical Associations (UATI) (224).

WEPSD's visions is (224):

> *"Engineers will translate the dreams of humanity, traditional knowledge, and the concepts of science into action through the creative application of technology to achieve sustainable development. The ethics, education, and practices of the engineering profession will shape a sustainable future for all generations. To achieve this vision, the leadership of the world engineering community will join together in an integrated partnership to actively engage with all disciplines and decision makers to provide advice, leadership, and facilitation for our shared and sustainable world."*

The WEPSD's mission is to (224):

- Assist and interact with all engineering organizations to promote sustainable human development;
- Develop constructive relationships with all other stakeholders having related goals;
- Propose and coordinate projects/programs that will facilitate sustainable development; and
- Represent the interests of engineering organizations in influencing public and private decisions in order to create a sustainable future.

American Public Works Association (APWA) and the Rebuild America Coalition

APWA is a not-for-profit organization dedicated to education in the related areas of public works. It helps its members, the public, and policy makers work together to provide the public works services needed to keep our communities operating smoothly and safely in concert with the latest environmental and public health standards. Figure 11.1 illustrates APWA's Code of Ethics for public works officials (235).

APWA's Rebuild America Coalition is a broad cooperative of public and private organizations committed to the infrastructure challenge. The Coalition includes mayors, county commissioners, city council members, and other public leaders responsible for maintaining, inspecting, and planning the building and rebuilding of our public facilities. They are supported by the engineers, builders, financiers, contractors, and architects whose careers are dedicated to the highest standards of quality, safety, and cost effectiveness. The Coalition believes that the nation's economic competitiveness and well-being are directly linked to the condition and quality of our infrastructure facilities and services. Members of the Coalition volunteer their time to help focus public attention on the serious problems associated with America's deteriorating infrastructure (235).

The Coalition has a wide and varied organizational membership of engineering and public service organizations and it believes that infrastructure must be a top national priority. The Coalition's mission in relation to infrastructure is to (235):

- Create public awareness of the need to increase infrastructure investment and the role of the infrastructure in building the nation's economy and improving the productivity of the nation;
- Promote the economic benefits of job creation through public and private infrastructure investment;
- Encourage government action at the federal, state and local levels to increase infrastructure funding;
- Encourage innovations in technology, financing, and public/private partnerships;
- Encourage formation of similar state and/or local coalitions; and
- Foster joint cooperation among the public and private sector organizations in support of resolving the nation's public works crisis.

To accomplish its mission, the Coalition has identified the following legislative goals (235):

1. There should be no further funding reductions in existing federal programs that address infrastructure needs.
2. The existing federal infrastructure trust funds must be continued, adequately funded, and fully expended for their intended purposes.
3. Federal restrictions on the use of tax-exempt financing for infrastructure purposes should be eliminated.

4. A federal capital infrastructure program should be created to provide assistance to the states and localities in meeting infrastructure needs.
5. A federal long-term, multi-year capital budget should be established.

AMERICAN PUBLIC WORKS ASSOCIATION CODE OF ETHICS

Recognizing their responsibilities to the people, desiring to inspire public confidence and respect for government, and believing that honesty, integrity, loyalty, justice, and courtesy form the basis of ethical conduct, members of the American Public Works Association:

- Uphold the Constitution, laws and regulations of their country and all other applicable units of government.
- Put public interest above individual, group, or special interest and consider their occupation an opportunity to serve society.
- Recognize that government service is a public trust that imposes responsibility to conserve public resources, funds, and materials.
- Recognize that political (policy) decisions are the responsibility of the people's elected representatives but that identification and communication of technical and administrative alternatives and recommendations as a basis for decision making are the responsibility of public works officials, professional engineers, or other administrators.
- Never offer, give, nor accept any gifts, favors, or service that might tend to influence them in the discharge of their duties.
- Never use their position to secure advantage or favor for themselves, their family, or friends.
- Never disclose confidential information gained by reason of their position, nor use such information for personal gain.
- Never make recommendations, while empoyed by a public agency, on any matter that involves a business in which they have a direct or indirect financial interest.
- Never engage in supplemental employment, business, or professional activity which impairs the efficiency of their services; or while employed by a public agency become involved in work which could come before their agency for review or inspection.
- Recognize that it is not in the public interest for officials of public agencies to select and retain professional engineering services on the basis of price alone and that consideration must be given to experience, technical expertise, availability, and other qualifications.
- Do not attempt either falsely or maliciously to injure the reputation, business, or employment status of any individual.

Figure 11.1 American Public Works Association Code of Ethics (106)

11.6 CIVIL ENGINEERING EDUCATION

The infrastructure crisis and sustainable development have put immense pressure on the civil engineer, making his/her job more complicated. To meet these two challenges, the civil engineer must be very multidisciplinary in education and thinking. His or her training must go beyond science and engineering, and include management, economics, sustainable development, financing, politics, law, sociology and urban planning.

Due to the evolving societal needs, the demand for design and construction engineers is declining, implying a need to refocus our municipal engineering courses to accommodate an orientation away from new development to a caretaking function, and to provide engineers political and managerial skills needed for the increasingly complex and competitive public service environment.

Universities have not been on the forefront of knowledge to reflect these societal shifts. Very few universities offer courses related entirely to maintenance and rehabilitation. If our society is changing direction from new development to maintaining what is already there, then the universities should recognize these changes and accommodate them .

Recognition of the shift to maintenance rather than new construction must come first from our civil engineering schools. Not only should they teach basic applied science principles, but also their application. This may be accomplished by either changing the practical application of applied science theory in selected case problems, or by providing a general course in public works administration (111).

The emerging concepts of sustainable development are adding another dimension and challenge to the planning and development of infrastructure. Civil engineers who will play a critical leadership role as facilitators of sustainable development, need to expand their skills, knowledge and understanding in areas such as environmental economic analysis, the creation of sustainable technologies and processes, integrated systems thinking and synthesis, and expanded multidisciplinary partnerships that can address cultural and social issues and differences (105). Therefore, professional education, training and apprenticeship is required to prepare designers for new technology and practice for achieving sustainable development.

Engineering educators need to produce graduates who can cope with the needs of the future. There will be an increasing demand on engineers to manage the infrastructure and more and more engineers must be trained as managers and program coordinators for complex utility systems designed and implemented by other technical disciplines (189). However, these changes should not just come about for graduate engineering students, but for undergraduates as well.

11.6.1 Need for a Revised Undergraduate Curriculum

While the current civil engineering curriculum has served society well to date, it is time to improve it and meet the demands of the changing world and increasing competition from abroad. Agogino and Ingraddea list the following critical problems in undergraduate engineering today (3):

- **Synthesis:** Students are taught too much content and not enough process. They are not exposed enough to synthesis and open-ended problem solving techniques.
- **Interdisciplinary Content:** The curriculum tends to be compartmentalized without enough interdisciplinary content.
- **Delivery Styles:** Delivery styles are outdated and not effectively utilize modern information technologies. In addition, learning style differences and cultural/ethnic diversity are not uniformly considered in the classroom.
- **Concurrent Engineering:** Concurrent application of multiple disciplines through the design cycle requiring team design experience is largely absent in the curriculum.
- **Industry:** There is not enough industrial practice and experience embedded in the curriculum.
- **Laboratory/Hand On:** Insufficient hands-on and laboratory experiences are offered to undergraduate students.
- **Curriculum turnover:** Curriculum turnover is too slow and mechanisms for bringing new research and technologies into the undergraduate classroom are lacking.
- **Social Context:** Engineers need to be able to evaluate and communicate social implications of technology, but societal factors are neglected in the conventional curriculum.

- **Communication:** Students lack adequate communication skills upon graduation.

The civil engineer of today and tomorrow must be more than a good designer. In addition, the civil engineering profession has a need for environmental scientists with regulatory backgrounds who understand not only the technicalities of projects, but the legalities as well. There is also a need for computer-literate professionals (189).

According to Yao, undergraduate engineering education must emphasize broad and general engineering education with a strong foundation in science and the curriculum must be expanded to include courses on humanities, economics, sociology, and work-orientation skills. In addition, elements of deterioration science, assessment technology, renewal engineering, and institutional effectiveness and productivity should be incorporated into introductory undergraduate courses (238).

Participants of the 1994 Civil Engineering Education Workshop gave the following definition of the undergraduate civil engineering degree (238):

"The intellectual foundation of the civil engineering undergraduate degree should be broad, well-rounded, multidisciplinary, and strong in technical and scientific knowledge, supplemented by exposure to:

- *a global vision and approach to problem identification and problem solving in areas such as infrastructure, environment, facilities, and systems;*
- *a basic management knowledge base in areas such as business, resources, costs and value judgments, and time management;*
- *a solid foundation in personal and interpersonal attributes, ethics, and social/humanities; and*
- *an involvement with engineering practice as the formal education evolves."*

The basic demand placed on civil engineers by infrastructure renewal is one of skills to carry out the activities. Table 11.1 summarizes the skills identified by Haas (109).

Table 11.1: Possible Skills Required for Infrastructure Renewal (109)

Non-Technical Skills	1. Financial planning 2. Public policy 3. Business administration 4. Personnel management 5. Engineering law 6. Public relations
Basic Skills	1. Computing 2. Data base design and management 3. Probability and Statistics 4. Mathematical modeling 5. Engineering economics
Technical and Special Skills	1. Geotechnical or geology 2. Building materials 3. Construction materials 4. Special materials 5. Materials testing 6. Field testing and instrumentation 7. Flow analysis (pipes and networks) 8. Hydrology and hydraulics 9. Water quality and treatment 10. Wastewater treatment 11. Traffic operations and analysis 12. Pavement engineering and management 13. Bridge engineering and management 14. Structural steel design 15. Structural concrete design 16. Construction engineering and management 17. Maintenance engineering and management
Other	1. Common sense

Incorporating Infrastructure Renewal

For infrastructure renewal, universities, in collaboration with the profession and industry should assume some additional responsibilities, including the following (109):

- Identify areas where basic skills require major upgrading or extension through graduate studies, specialty workshops, etc.;
- Encourage faculty to obtain experience with renewal and rehabilitation problems;
- Upgrade textbooks with examples of re-design and encourage research on infrastructure problems and the development of improved technologies;
- Communicate the fact that the civil engineering professional environment is becoming one of engineering and managing renewal and that this offers just as great,

or greater challenges and responsibilities than those that accompany engineering of new works;

- Develop better estimates of the number of civil engineers and associated skills required over the next decade or more;
- Organize professional seminars, workshops, courses, etc. dealing with infrastructure renewal problems and provide formalized sets of case studies; and
- Establish formal links with practicing experts in the various areas of urban infrastructure.

Incorporating Sustainable Development

"Civil Engineers must become advocates of sustainable development for the planet. This is in their global interest, their nation's interest and in their own personal interest. It is essential that the Civil Engineering profession becomes involved in alerting the public, politicians and governments to the urgency of seeking solutions to global problems." (137)

However, before Civil Engineers go about educating others about ways of achieving sustainable development and its importance in the preservation of our natural resources and environment, they first need to educate themselves. And the best time to learn is at the undergraduate level where these new values can become part of their system and their practice from the very first day they start practicing. Sustainability issues should therefore be integrated within Civil Engineering course material. The following are possible discussion topics for the five major civil engineering sub-disciplines (136):

Structural Engineering:

- Environmental characteristics of building materials;
- Environmental impact of building demolition;
- Energy considerations for design;
- Retrofitting;
- LCC analysis;
- Consideration of material recycling; and
- Material durability considerations.

Geotechnical Engineering:

- Soil contamination issues;
- Leachate collection systems in landfills;
- Ecosystem effects of earth/rock dam construction;
- Acquifer pumping and overdraft problems;

- Dewatering consequences;
- Irrigation-soil salinity problems; and
- Mine tailing effects and stability failures.

Transportation Engineering:

- Public transit considerations;
- Motivating bicycle usage;
- Air and noise pollution levels;
- Full cost accounting and comparisons of rail vs. truck transport; and
- Land use and inner city consequences of urban sprawl.

Construction Engineering:

- Affordable housing construction;
- Durability of building materials;
- Potential for recycling building materials;
- Byproduct material handling and recovery; and
- Impacts on water course from poor construction practices.

Environmental/Water Resources Engineering:

- Conservation and waste minimization;
- Recycling;
- Composting;
- Groundwater contamination issues and prevention; and
- Energy efficient waste treatment.

As it can be seen, drastic changes are needed in both engineering practice and education to assure a sustainable future since engineers, who are responsible for a lot of the degradation of our planet are the key to educating the society as a whole in following a sustainable path.

Engineering education must instill in its students an early respect and ethical awareness for sustainable development along with an understanding and appreciation of cultural and social characteristics and differences among the various world communities. In addition, engineering students must possess the analytical tools to assess risks and impacts, to perform life cycle analysis, and the ability to solve technical problems, taking into consideration the economic, socio-political and environmental implications.

Engineers must strive to educate all elements of the society and promote universal adoption of a sustainable development ethic among private and public sector decision makers, developers, investors, and local, regional, national, and international governing bodies (1).

Since adversarial relationships in the construction process often result in litigation and other detrimental actions, future stakeholders must be trained at colleges, workplaces, and community centers, on cooperative methods for resolving potential disputes (38).

11.6.2 A Revised Undergraduate Curriculum

It can be seen that in order for the civil engineer to meet the challenges of the future, their undergraduate and graduate education needs a drastic overhaul. The civil engineering curriculum must become multidisciplinary. Students must be made aware of the infrastructure crisis and sustainable development, very early in their undergraduate education. It would be best for the principles of infrastructure renewal and sustainable development to be integrated in all civil engineering courses, so that the students' knowledge goes beyond the comprehension of the principles, and incorporates its application and solution. For instance, all design courses should emphasize renewal, LCC, and sustainable development and supplement them with specific case studies and examples. In addition to the traditional civil engineering courses, the undergraduate curriculum should incorporate at least one course focusing on each of the following, while applying them in all relevant courses:

- CADD and Information Systems (including Decisions Support Systems)
- Management;
- Public Administration;
- Financing;
- Economics;
- Political Science;
- Law;
- Infrastructure and Society;
- Sustainable Development; and
- Urban Planning.

Many would argue that there is no room to add to the current undergraduate course load and these courses should be given as electives, or at the graduate level. However, there are several courses that could be consolidated to make room for new one. For instance McGill University consolidated the courses Fluid Mechanics and Hydraulics into Fluid Mechanics and Hydraulics I, and II, offering the second part as an elective. In addition, many civil engineers do not go for a graduate degree in civil engineering, and would therefore graduate quite ignorant of the challenge facing them in the real world and lack the skills required to solve them.

Table 11.2 summarizes courses that should be taught at the undergraduate level to prepare future engineers for the challenges ahead. A degree with such courses will be far more practical and useful for the challenges in practice and for the industry, than the one that is currently available to students. In addition, if these civil engineers are not taught these additional skills, they will not be able to pass on their knowledge to practicing engineers who need to be made aware of the various issues affecting our society. Therefore, a revised curriculum will not only make a civil engineer more marketable, but also prepare him/her for the challenges ahead.

Table 11.2: Proposed Courses for Current and Future Civil Engineering Needs

Required Courses	Electives
1. Computing for Civil Engineers (including information systems, data base design, decision support systems, Internet, web page development, multimedia, etc.) 2. Statics 3. Dynamics 4. Solid Mechanics 5. Surveying 6. Civil Engineering Systems Analysis (network analysis, linear programming, etc.) 7. Environmental Engineering 8. Written Communications Skills 9. Transportation Engineering (including the principles of sustainable development) 10. Probability and Statistics 11. Calculus 12. Differential Equations 13. Numerical Methods 14. Structural Engineering I (including the principles of sustainable development) 15. Structural Engineering II (including the principles of sustainable development) 16. Graphics (including manual drafting and CAD) 17. Engineering Economics (including LCC analysis) 18. Sustainable Development 19. Introduction to Urban Planning (including the principles of sustainable development) 20. Management for Civil Engineers (including financial planning, personnel management, accounting and the principles of sustainable development) 21. Politics and Law for Civil Engineers (including public policy and public relations) 22. Geotechnical Engineering (including the principles of sustainable development) 23. Construction Materials I (including the principles of sustainable development) 24. Fluid Mechanics and Hydraulics I (including the principles of sustainable development) 25. Construction Engineering (including the principles of sustainable development) 26. Construction Project Management (including the principles of sustainable development) 27. Maintenance Engineering I (including needs assessment, condition assessment, etc.) 28. Project	1. Public Works Administration 2. Public Policy for Civil Engineers 3. Financing Infrastructure 4. Water quality and treatment 5. Wastewater treatment 6. Traffic Engineering 7. Pavement Engineering and Management (including the principles of sustainable development) 8. Bridge engineering and management (including the principles of sustainable development) 9. Structural Steel Design (including the principles of sustainable development) 10. Structural Concrete Design (including the principles of sustainable development) 11. Matrix Structural Analysis 12. Municipal Systems (including the principles of sustainable development) 13. Fluid Mechanics and Hydraulics II (including the principles of sustainable development) 14. Geoenvironmental Engineering (including the principles of sustainable development) 15. Construction Materials II (including the principles of sustainable development) 16. Structural Dynamics 17. Structural Mechanics 18. Solid Waste Management (including the principles of sustainable development) 19. Maintenance Engineering II (including the principles of sustainable development) 20. Urban Transportation Planning (including the principles of sustainable development) 21. Rail Engineering 22. Durability of Structures (including the principles of sustainable development) 23. Water Resources Management 24. Stream Pollution and Control 25. Hydraulics Structures 26. Fluid Mechanics of Air Pollution 27. Fluid Mechanics of Water Pollution 28. etc.

11.7 SUMMARY

Civil engineers must recognize that the current and future infrastructure needs are great, and our past ways of dealing with them are inadequate. All civil engineers, whether they are designers, researchers, contractors, educators, or public officials, need to consider new ideas and new ways of getting their work done. They must also work together to get the research out of the laboratory and into practice (23).

There is a need in Canada for organizations such as CERF and the Rebuild America Coalition, that focus on the needs of infrastructure through lobbying efforts, coordinating research, formulating policy and legislation, etc., since organizations such as the FCM guard the interests of their members and therefore lack the attention and focus needed for infrastructure renewal. The new organization(s) should focus on infrastructure to meet the needs of the entire society, and not just one group.

The civil engineering profession has a very important role to play to achieve success in infrastructure rehabilitation. The profession must have an adequate number of skilled and trained people capable of evaluating conditions of urban infrastructure, identifying feasible and economical alternatives, and implementing them. This can only be achieved only by emphasizing the teaching of fundamentals of materials science and rehabilitation as opposed to new construction at the educational institutions. Also, with increased cooperation between educators, civil engineering organizations such as the ASCE and CSCE, and practitioners, the provision of continuing education programs to retrain current engineers. Licenses should not be renewed unless a required number of continuing education courses are taken. Finally, the reward system for engineers must reflect the increasing importance of rehabilitation, maintenance and operation as compared to new works, since there is little glamour and low pay associated with these practices (120).

The most pressing requirement of the civil engineering profession is to create public awareness of the extent of deterioration of our infrastructure, its economic and social impacts, the urgent need to take immediate action before the costs become prohibitive and our economic growth and standard of living seriously decline. It should share this responsibility with the different levels of government and industry (109). In the US, a large amount of public awareness has been created, and federal, state and local representatives are sponsoring major legislative and funding programs. Powerful private sector and public sector coalitions have been the key to creating this awareness and promotion (109).

The universities are producing students that are narrowly focused and not equipped to face the competitive industry today. Frankly, we are systematically losing those very students who could provide leadership in business and public policy. Therefore, universities must learn to recognize societal shifts and alter their institutions to accommodate these changing requirements to ensure that the engineering profession continues to satisfy the needs of our changing and complex society. Civil engineering education must stress maintenance and rehabilitation of infrastructure facilities and develop basic design education that incorporates the multidimensional nature of design for sustainability,. In addition, continued emphasis must be placed on the need to comprehend the society's administrative and political processes.

If engineers fail to accept the challenge of sustainable development, then the decision-making processes that influence and shape the future of our world will leave us behind. They cannot risk the consequences of a future built on an unsustainable foundation. They have the huge responsibility if ensuring that future generations get their heritage.

Poggemeyer put is best by stating (189):

> ***We, as engineers, know the problems!***
> ***We, as engineers, know the solutions.***
> ***And we, as engineers, had better take the lead!***

12.0 SUMMARY AND CONCLUSIONS

Infrastructure is the foundation and the basic framework that facilitates the functioning of our cities and has many social, economic, managerial, financial, political, legal and environmental implications. There is a significant infrastructure problem in North America. In cities across North America, the infrastructure is wearing out. Pubic works infrastructure did not deteriorate overnight. Rehabilitation of post-war infrastructure did not become necessary until much of it began to reach the end of its useful life during the 1970s. Infrastructure facilities such as parks and recreation and social services, began to get a larger share of the municipal budgets. This was followed by a period of high interest rates in the 1980s and a strong reluctance on the part of municipal governments to use debt financing. In addition, time and expense were added to projects as public participation in the decision making process increased. In addition, most federal programs had emphasized new construction rather than reconstruction of existing infrastructure.

Steps should be taken immediately to halt the trend towards infrastructure decline. Without jeopardizing the provision of new facilities to meet growth, a greater emphasis should be placed on maintenance and reconstruction of infrastructure rather than construction of new infrastructure.

Over the past 50 years, engineering and construction practices have proved to be detrimental to the environment and our natural resources. The practicing engineers must stop inflicting any further damage on the state of our planet and try to solve what has already been damaged. The future role of civil engineers should be the prevention of any damage to our environment and natural resources, and this can be achieved by incorporating sustainability into the current civil engineering practices.

The management of infrastructure plays a crucial role in its maintenance and upkeep. Developing an effective management approach is a long-term way to handle a problem as large as our current infrastructure crisis since engineering skills alone will not be adequate to resolve this crisis. In addition, the different levels of government do not have the financial means of upgrading or maintaining our infrastructure at an acceptable level and are faced with the challenge of finding alternative sources of funding. This would require them to educate themselves and inevitably tap the private sector to ensure the provision of safe and efficient infrastructure facilities.

The initial and life-cycle costs of municipal infrastructure renewal depend on the technology used to build it. Although many new technologies have been developed in Canada and abroad, their practical use has not developed a great deal. Research and development reduces costs and improves a nation's quality of life and competitiveness. Innovative and up-to-date technologies can guarantee efficient, safe, effective service and contribute to economic growth. The level of effort and resources applied to infrastructure research and development falls short of the current and future requirements. Therefore, a careful investment in research, development and technology transfer, is an essential part of a national infrastructure renewal strategy.

Although there is a greater public awareness of the infrastructure issues than ten years ago, efforts should be made to continue to inform the public of the need for necessary remedial measures, especially for those facilities that are underground and are not visible.

Government, industry, academia, and the professions need to be united to meet the infrastructure needs of the 21st century. Our leaders must develop a strategy to focus on meeting our vast infrastructure needs, establishing priorities with the greatest economic and environmental returns and developing sources of funding. They must look into formulating an infrastructure policy and other economic instruments that would aid in design and construction of sustainable facilities.

The heaviest burden of taking action on the infrastructure crisis and it sustainable development, falls on the shoulders of civil engineers. They have a very important role to play in ensuring a safe, reliable and environmentally friendly infrastructure for the future. This is not going to be an easy task since this would require civil engineers to enter the political arena and most of all, educate themselves and future engineers about the infrastructure crisis, its sustainable development, and what they can do about solving the current problem and preventing further deterioration. They should encourage Canadian universities and colleges to initiate courses on infrastructure management, maintenance, and rehabilitation of infrastructure, at both the undergraduate and graduate levels, and provide for continuing education for practicing engineers.

So where do we go from here? To solve the current infrastructure crisis, it is essential to adopt the principles of sustainable development and face the challenges ahead. We, as civil engineers should focus on the following:

- Determine the actual situation of the infrastructure (needs and condition assessment);
- Design and construct sustainable infrastructure and communities;
- Familiarize ourselves with the new management techniques available to better manage our infrastructure and its sustainable development;
- Use alternative financing mechanisms to fund infrastructure renewal, particularly public-private partnerships (PPP);
- Enter the political arena as lobbyist and politicians;

- Promote research, development and innovation in infrastructure and sustainable development related areas;
- Drastically change the civil engineering curriculum to meet the needs of the future;
- Better educate ourselves and the society; and
- Create a national infrastructure policy and an organization dealing with infrastructure needs.

13.0 REFERENCES

1. AAES, *The Role of the Engineer in Sustainable Development*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 3-6

2. Agopyan, V., and de Paula, T., *Construction Wastes as Raw Materials for Low-Cost Construction Products*, Sustainable Construction, Proceedings of the First International Conference of CIB TG 16, International Council for Building Research, Center for Construction and Environment, University of Florida, Tampa, 1994, pp. 335-342

3. Agugino, A. M., and Ingraffea, A. R., *Integrating the Undergraduate Engineering Curriculum*, Computing in Civil Engineering and Geographic Information Systems Symposium, 1992, pp. 356-363

4. Aley, B., and Choate, C., *Hypermedia Support for Infrastructure Planning and Management*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp. 71-75

5. Amboski, D. and Slack, E., *Federal, Provincial, Municipal Co-operation: Past, Present and Future*, The Proceedings of the First Canadian Conference on Infrastructure, Edmonton, 1987

6. Appelbaum, S. H., Certo, S. C., and Shapiro, B., *Modern Management in Canada: Quality, Ethics, and the Global Environment*, Prentice Hall, Scarborough, 1993

7. Arditi, D. A., and Messiha, H. M., *Life-Cycle Costing in Municipal Construction Projects*, Journal of Infrastructure Systems, March 1996, pp. 5-14

8. Arens, A. A., Lemon, W. M., and Loebbecke, J. K., *Auditing: An Integrated Approach*, Prentice Hall Canada Series in Accounting, Scarborough, 1993

9. Armour, J., *Urban Growth and Public Works Planning*, Proceedings of Public Works and Society, American Society of Civil Engineers, The Institution of Civil Engineers (UK), Florida, 1972, pp. 3-12

10. ASCE, *Official Register*, Washington, D.C., 1997

11. ASCE, *Research Needs Related to the Nation's Infrastructure*, Proceedings of the Workshop Sponsored by the National Science Foundation and the American Society of Civil Engineers, New York, 1984

12. ASCE, *The Infrastructure Problem and the Role of the Civil Engineer*, Civil Engineering, October 1982, pp. 41-43

13. Ausubel, J. H., and Herman, R., *Cities and Infrastructure: Synthesis and Perspectives*, Cities and their vital systems: Infrastructure Past, Present, and Future, National Academy of Engineering, Washington, D.C., 1988, pp. 1-21

14. Bacon, K. M., *Legislative Trends Affecting the Funding of Public Works*, Infrastructure for Urban Growth, Proceedings of the Specialty Conference Sponsored by the Urban Planning and Development and Urban Transportation Divisions of the American Society of Civil Engineers, New York, 1985, pp. 174-177

15. Bagnall, J., *R&D Benefits Business*, The Ottawa Citizen, February 2, 1994

16. Baker, N. C., and Rix, G. J., *The Status of Computing in Civil Engineering: Curriculum vs. Practice*, Computing in Civil Engineering and Symposium on Data Bases, 1991, pp. 900-919

17. Baldry, D., and Golton, B., *Project Management for Sustainable Construction*, Sustainable Construction, Proceedings of the First International Conference of CIB TG 16, International Council for Building Research, Center for Construction and Environment, University of Florida, Tampa, 1994, pp. 667-675

18. Bamberger, R. J., Blazer, W. A. and Peterson, G. E., *Infrastructure Support for Economic Development*, American Planning Association, Washington, D. C., 1985

19. Bannister, D., and Button, K., *Environment Policy and Transport: An Overview*, Transport, the Environment and Sustainable Development, UK, 1993, pp.19-52

20. Barfield, J. T., Kinney, M. R., and Raiborn, C. A., *Managerial Accounting*, West Publishing Company, St.-Paul, 1992

21. Bartholomew, K., Burwell, D., and Gordon, D., *Energy and Environmental Research Needs*, Transportation, Urban Form, and the Environment, Irvine, 1990, pp.81-100

22. Beesley R., and Kirby R., *The Federal Role in Infrastructure Renewal*, Urban Institute, Washington, D.C., 1983

23. Bernstein, H. M., *Is the Design and Construction Industry Up to the Challenge?*, Journal of Infrastructure Systems, September 1995, pp. 143-145

24. Bordogna, J., *Civil Infrastructure Systems: Ensuring Their Civility*, Journal of Infrastructure Systems, pp. 3-5

25. Borg, N., *Re-Cycling of Land Resources*, Proceedings of Public Works and Society, American Society of Civil Engineers, The Institution of Civil Engineers (UK), Florida, 1972, pp. 39-48

26. Bossink, B. A. G., and Brouwers, H. J. H., *Construction Waste: Quantification and Source Evaluation*, Journal of Construction Engineering and Management, March 1996, pp. 55-59

27. Bradley, J., *Political and Financial Challenges of Infrastructure Renewal*, The Proceedings of the First Canadian Conference on Infrastructure, Alberta, 1987, p.31

28. Brand, D., *Research Needs for Analyzing the Impacts of Transportation Options on Urban Form and the Environment*, Transportation, Urban Form, and the Environment, Irvine, 1990, pp.101-116

29. Bregha, F., and Moffet, J., *The Role of Law Reform in the Promotion of Sustainable Development*, Journal of Environmental Law and Practice, Volume 6, #1, 1995, pp.1-21

30. Canada Infrastructure Works, *Fact Sheet*, Government of Canada, Ottawa, 1994

31. Canada Infrastructure Works, *News Release*, Government of Canada, Ottawa, 1994

32. Canadian Water and Waste Water Association, January/February Forum, 1996

33. Caron, C., As a Society, *We've Paid High Price for Urban Sprawl*, The Gazette, February 12, Montreal, 1997

34. Cassils, J. A., *Exploring Incentives: An introduction to Incentives and Economic Instruments for Sustainable Development*, National Round Table on the Environment and the Economy, Ottawa, 1991

35. CERF, *Setting A National Research Agenda for the Civil Engineering Profession*, Civil Engineering Research Foundation, Washington, D. C., 1991

36. CERF, *Assessing Global Research Needs*, Symposium on Engineering and Construction for Sustainable Development in the 21st Century, Civil Engineering Research Foundation, Washington, D. C., 1996

37. CERF, *Bridging the Globe: Highlights from the Symposium*, Symposium on Engineering and Construction for Sustainable Development in the 21st Century, Civil Engineering Research Foundation, Washington, D. C., 1996

38. CERF, *Bridging the Globe: Engineering and Construction Solutions for Sustainable Development in the Twenty-First Century*, Symposium on Engineering and Construction for Sustainable Development in the 21st Century, Civil Engineering Research Foundation, Washington, D. C., 1996

39. CERF, *Constructed Civil Infrastructure Systems R&D: A European Perspective*, Civil Engineering Research Foundation, Washington, D. C., 1994

40. CERF, *Federal Public Works Infrastructure R&D: A New Perspective*, Washington, D.C., 1993

41. Chong, K. P., Lemer, A. C., and Tumay, M. T., *Research as a Means for Improving Infrastructure*, Journal of Infrastructure Systems, pp. 6-15

42. Christian J. W., *Financing Infrastructure Maintenance through Public Trusts*, Capital Projects: New strategies for Planning, Management, and Finance, Washington, D.C., 1989

43. Ciesielski, S. K., and Collins, R. J., *Recycling and Use of Waste Materials and By-Products in Highway Construction*, National Cooperative Highway Research Program, National Academy Press, Washington, D.C., 1994

44. Civil Infrastructure Task Group, *Civil Infrastructure Systems Research: Strategic Issues*, National Science Foundation, Washington, D. C., 1993

45. Class Notes, 303-527 Renovation and Preservation of Infrastructure, McGill University, 1993

46. CMHC, *Public-Private Partnerships: Theory and Practice*, Canada Mortgage and Housing Corporation, Ottawa, 1995

47. CMHC, *Urban Infrastructure in Canada*, Canada Mortgage and Housing Corporation, Ottawa, 1992

48. CMHC, *The Integrated Community: A Study of Alternative Land Development Standards*, Canada Mortgage and Housing Corporation, Ottawa, 1996

49. Committee on Infrastructure, *In Our Own Backyard: Principles for Effective Improvement of the Nation's Infrastructure*, Building Research Board, Commission on Engineering and Technical Systems, National Research Council, Washington, D. C., 1993

50. Commoner, B., *Making Peace With the Planet*, The New Press, New York, 1992

51. Condreay, E. S., *Infrastructure: Rehabilitation or New*, Rebuilding America: Infrastructure Rehabilitation, American Society of Civil Engineers, New York, 1984, pp. 122-123

52. Conklin, D, Hodgson, R. C., and Watson, E. D., *Sustainable Development: A Manager's Handbook*, National Round Table on the Environment and the Economy, Ottawa, 1991

53. Cooper, S., *The Next Public Works Program*, Social Policy, Winter 1987, pp. 14-19

54. Craven, D. J., Eilenberg, I. M., and Orkraglik, H., *Construction Waste and New Design Methodology*, Sustainable Construction, Proceedings of the First International Conference of CIB TG 16, International Council for Building Research, Center for Construction and Environment, University of Florida, Tampa, 1994, pp. 89-98

55. Cristofano, S. M., *Identifying Goals - Establishing the Framework*, Rebuilding America: Infrastructure Rehabilitation, American Society of Civil Engineers, New York, 1984, pp. 46-52

56. Culver, C. G., *Structural Standards Activities Related to the Infrastructure*, Infrastructure: Maintenance and Repair of Public Works, New York, 1984, pp. 104-112

57. Curtis, L. W., *Strategic Planning for Infrastructure Redevelopment*, Rebuilding America: Infrastructure Rehabilitation, American Society of Civil Engineers, New York, 1984, pp. 91-94

58. Curtis, W. H., *State of Urban Infrastructure in Canada*, The Proceedings of the First Canadian Conference on Infrastructure, Edmonton, 1987, p.1

59. D'Amour, D., *The Origins of Sustainable Development and its Relationship to Housing and Community Planning*, Canada Mortgage and Housing Corporation, Ottawa, 1991

60. D'Amour, D., *Towards an Investigation of Sustainable Housing*, Canada Mortgage and Housing Corporation, Ottawa, 1993

61. Davis, B. S., *Legislating for Infrastructure Investment*, Rebuilding America: Infrastructure Rehabilitation, American Society of Civil Engineers, New York, 1984, pp. 242-250

62. Deakin, E., *Jobs, Housing, and Transportation: Theory and Evidence of Interactions Between Land Use and Transportation*, Transportation, Urban Form, and the Environment, Irvine, 1990, pp.25-62

63. DeGagne, A. J., *The Reality of Municipal Financing: Why has Public Works Lost Out in Recent years?*, The Proceedings of the First Canadian Conference on Infrastructure, Edmonton, 1987, p.63

64. Deighton, R., and Lee, H., *Information Technology for Infrastructure Management*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp. 147-151

65. Deighton, R., and Lee, H., *Developing Infrastructure Management Systems for Small Public Agency*, Journal of Infrastructure Systems, December 1995, pp. 230-234

66. Denham, R., Morrison, K. A., Perks, A. R., *Integrated Management of Municipal Infrastructure*, Proceedings of the 1995 Annual CSCE Conference, Canadian Society for Civil Engineers, 1995, pp. 653-662

67. Doerring, R. L., and Runnalls, D., *Sustainability: The Key to Competitiveness in the 21st Century*, National Round Table on the Environment and the Economy, Institute for Research on Public Policy, Ottawa, 1993

68. Downey, M. L., *Infrastructure: Can We Renew It? - Should We Renew It?*, Infrastructure for Urban Growth, Proceedings of the Specialty Conference Sponsored by the Urban Planning and Development and Urban Transportation Divisions of the American Society of Civil Engineers, New York, 1985, pp. 85-96

69. Dunlop, J. T., *Rebuilding America's Vital Public Facilities*, America's Infrastructure: Problems and Prospects, R. L. Kemp, ed., Danville, 1986, p.29

70. Echeverry, D., and Ibbs, C. W., *New Construction Technologies for Rebuilding the Nation's Infrastructure*, Cities and their vital systems: Infrastructure Past, Present, and Future, National Academy of Engineering, Washington, D.C., 1988, pp. 294-311

71. Egan, J. C., *Legislation Needed for the Construction, Operation, and Maintenance of Our Public Buildings*, Infrastructure: Maintenance and Repair of Public Works, New York, 1984, pp. 69-81

72. Ehrlich, P., and Ornstein, R., *New Mind New World: Moving Toward Conscious Evolution*, Simon & Shuster Inc., New York, 1989

73. Elkin, Duncan McLaren and Mayer Hillman, *Reviving the City: Towards Sustainable Urban Development*, Friends of the Earth, Policy Studies Institute, UK, 1991

74. Engelmann, P., *Infrastructure Planning for Private Sector Investment*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp.403-412

75. Erickson, R., *Recent Developments in Innovative Finance*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp. 36-40

76. Ernst, W. and Grasewicz, P. J., *Impact Fees: When, Where, and How?*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989

77. Essiambre, R., and Ferguson, K., *Cost Savings through Alternative Planning Approaches*, Proceedings: Workshop on Municipal Infrastructure and Housing, Canada Mortgage and Housing Corporation, Ottawa, 1995, pp. 31-56

78. Essiambre-Phillips-Desjardins Associates Ltd., *Infrastructure Costs Associated with Conventional and Alternative Development Patterns*, Summary Report, Workshop on Municipal Infrastructure and Housing, Canada Mortgage and Housing Corporation, Ottawa, 1995

79. FCM, *Rebuilding for a Competitive Canada*, The Federation of Canadian Municipalities, Ottawa, 1993

80. FCM, *Municipal Infrastructure in Canada: Physical Condition and Funding Adequacy*, The Federation of Canadian Municipalities, Ottawa, 1985

81. FCM, *"Green Card" Report*, Ottawa, Sept.-Oct. 1992

82. FCM, *Backgrounder: Municipal Infrastructure*, Ottawa

83. FCM, *Review of FCM involvement in infrastructure Lobby: Backgrounder No. 3A*, Ottawa

84. Felio, G., and McDonald, S., *Assessing the Condition of Municipal Infrastructure*, Executive Report, Workshop on Municipal Infrastructure and Housing, Canada Mortgage and Housing Corporation, Ottawa, 1995

85. Felio, G., *Assessing Municipal Infrastructure Conditions*, Proceedings: Workshop on Municipal Infrastructure and Housing, Canada Mortgage and Housing Corporation, Ottawa, 1995, pp. 7-30

86. Felio, G., Seaden, G., and Walt, G., *A Proposed Technical Guide for Infrastructure for Canada*, National Research Council Canada, Ottawa, 1994

87. Felio, G. and McDonald, S., *Assessing the Condition of Municipal Infrastructure: Results From a Survey on the Measurements Used by Municipalities to Assess the Condition of their Infrastructure*, Canada Mortgage and Housing Corporation, National Research Council Canada, Ottawa, 1995

88. Fergusen, K. W., and Richardson, N. H., *Changing Values, Changing Communities: Evaluating Alternative Approaches to Residential Development*, Workshop on Municipal Infrastructure and Housing, Canada Mortgage and Housing Corporation, Ottawa, 1995

89. FIDIC, *Environmental Policy Statement*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 15-17

90. Field, T., *Municipal Infrastructure: Scope for Achieving Cost Efficiency/ Effectiveness Through Technical Innovations*, Canada Mortgage and Housing Corporation, Ottawa, 1992

91. Fields, D., and Ruitenbeek, J., *Sustainability and Prosperity: The Role of Infrastructure*, National Round Table on the Environment and the Economy, Ottawa, 1992

92. Finsterbusch, K., *Social Impacts Assessment: The Effects of Public Projects*, Page library at Social Research, Volume 110, 1980

93. Fischer, V. C., *States Rescue Localities with Creative Financing*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989

94. Fisk, E. R., *Construction Project Administration*, Prentice Hall, New Jersey, 1988

95. Gates, C., *Information Dissemination*, Proceedings: Workshop on Municipal Infrastructure and Housing, Canada Mortgage and Housing Corporation, Ottawa, 1995, pp. 82-98

96. Gates, C. and Ramsay, J., *An Assessment of Municipal Infrastructure Needs*, Canada Mortgage and Housing Corporation, Ottawa, 1995

97. General Accounting Office, *Value Engineering: What It Is and How It Works*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989, pp. 217-224

98. Giglio, J. M., *Infrastructure in Trouble*, Capital Projects: New Strategies for Planning, Management, and Finance , Washington, D.C., 1989, p.13

99. Godwin, S. R., and Peterson, G. E., *Infrastructure Inventory and Condition Assessment: Tools for Improving Capital Planning and Budgeting*, Department of Housing and Urban Development, Office of Policy Development and Research, Washington D. C., 1983

100. Godwin, S. R. and Peterson, G. E., *Developing a Comprehensive Condition Assessment System*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989, pp. 65-73

101. Gole, B. S., *Accounting for our Infrastructure*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989, pp. 61-64

102. Gordon, M., *Structuring Sustainable Construction Contracts*, Proceedings: 1st Transportation Specialty Conference, Volume 3a, 1996 Annual Conference, Canadian Society for Civil Engineers, Edmonton, 1996,, 1996, pp. 91-103

103. Gordon, M., *Construction and Demolition Waste Reduction, Recycling and Reuse- An effective Strategy for Projects Falling Outside Current Legislation Mandates*, Proceedings of the 1995 Annual CSCE Conference, Canadian Society for Civil Engineers, 1995, pp. 663-672

104. Government Finance Research Center, *Building Prosperity: Financing Public Infrastructure for Economic Development*, Municipal Finance Officers Association, Washington, D. C., 1983

105. Grant, A. A, *Civil Infrastructure Systems: The Big Picture*, Journal of Infrastructure Systems, June 1995, pp. 78-81

106. Grigg, N. S., *Infrastructure Engineering and Management*, New York, 1988

107. Grivas, D. A., and Shen, Y., *Decision-Support System for Infrastructure Preservation*, Journal of Computing in Civil Engineering, January 1996, pp. 40-49

108. Gullo, T., Parham D. and Petersen G. E., *The Role of Standards in Infrastructure Management*, The Urban Institute, Washington, D.C., 1984

109. Haas, R., Heinke, G., and Smith, D. W., *Infrastructure Renewal: Opportunities and Challenges for Civil Engineers*, 1991 Annual Conference of the Canadian Society for Civil Engineers, Vancouver, 1992, pp. 375-384

110. Hamilton-Wentworth, *The Official Plan*, The Regional Municipality of Hamilton-Wentworth, 1993

111. Hand, T. D., and Lenox, T. A., *Progressive Integration of the Personal Computer into an Undergraduate Civil Engineering Curriculum*, Computing in Civil Engineering and Geographic Information Systems Symposium, 1992, pp. 65-72

112. Handa, V. K., *Construction Engineering Driving into the 21st Century*, Journal of Construction Engineering and Management, March 1996, pp. 2-6

113. Hanson, R. D., *Educating Engineers for Rebuilding Rather than Building*, Infrastructure: Maintenance and Repair of Public Works, New York, 1984, pp. 176-181

114. Harris, S. W., *Role of Government in Public Works Development*, Proceedings of Public Works and Society, American Society of Civil Engineers, The Institution of Civil Engineers (UK), Florida, 1972, p. 167-176

115. Hastak, M., Maldonado-Fortunet, F., and Vanegas, J. A., *Conceptual Framework for Sustainable Quality Management*, Proceedings of the 1995 Annual CSCE Conference, Canadian Society for Civil Engineers, 1995, pp. 389-398

116. Hatch, H., *Accepting the Challenge of Sustainable Development*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp.33-39

117. Hatch, R., and Kroenke, D., *Business Information Systems: An Introduction*, McGraw-Hill, New York, 1993

118. Hatry, H. P., *Maintaining the Existing Infrastructure: Overview of Current Issues and Practices in Local Government Planning*, The Urban Institute, 1982

119. Hawken, P., *The Ecology of Commerce: A Declaration of Sustainability*, Harper Business, New York, 1994

120. Heinke, G. W., *Urban Infrastructure Rehabilitation in Canada*, Journal of Professional Issues in Engineering, Vol. 114, No. 4, October 1988, pp. 487-493

121. Henton, D. C., and Waldhorn, S. A., *The Future of Urban Public Works: New Ways of Doing Business*, Perspectives on Urban Infrastructure, National Research Council, Committee on National Urban Policy, Commission on Behavioral and Social Sciences and Education, National Academy Press, Washington, D.C., 1984, pp. 178-210

122. Hygeia Consulting Services and Reic Ltd., *Changing Values Changing Communities: A Guide to the Development of Healthy Sustainable Communities*, Canada Mortgage and Housing Corporation, Ottawa, 1995

123. Hyman, W. A., Kingsley, G. T., Miller, T. R., and Walker, J. C., *Impact of Global Climate Change on Urban Infrastructure*, The Urban Institute, Washington, D.C., 1988

124. IBI Group, *Achieving Infrastructure Efficiency*, Canada Mortgage and Housing Corporation, Ottawa, 1992

125. IBI Group, *Urban Travel and Sustainable Development: The Canadian Experience*, Canada Mortgage and Housing Corporation, Ottawa, 1993

126. Informatica, *Incremental Spending for Municipal Infrastructure Assessment of a $5.5 Billion Program*, November 5, 1987

127. Informetica, *Financing Municipal Infrastructure: Alternative Methods*, Canada Mortgage and Housing Corporation, Ottawa, 1992

128. Informetica Ltd., *The Macroeconomic Impact of Accelerated Spending on Municipal Infrastructure*, The Federation of Canadian Municipalities, Ottawa, 1985

129. Institute for Research in Construction, *A Review of Canada's Physical Infrastructure*, National Research Council Canada, Ottawa, 1993

130. Institution of Engineers-Australia, *Environmental Principles for Engineers*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 18-22

131. Ircha, M. C., *Municipal Engineering: Shifting to a Maintenance Perspective*, Engineering Education, May 1982, pp. 815-817

132. Ircha, M. C., *Canada's Municipal Infrastructure: Problems and Prospects*, Municipal World, July 1985, p174

133. Ircha, M. C., *Municipal Infrastructure: An International Review*, Planning and Administration, Spring 1986, pp. 6-13

134. Jacobson, N. G., and Tarhan, Y. M., *Automating Inventory and Assessment of Infrastructure*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp. 197-201

135. Jessen, K., *The Infrastructure and the Civil Engineer*, Journal of Professional Issues in Engineering, Vol. 110, No. 4, October 1984, pp. 151-156

136. Johnson, C. D. and Korol, R. M., *Embracing the concept of Sustainability into Civil Engineering Curricula and Practice*, Proceedings of the 1995 Annual CSCE Conference, Canadian Society for Civil Engineers, 1995, pp. 603-612

137. Johnson, C. D. and Kramer, J. M., *An Overview of the Canadian Society for Civil Engineering Guidelines for Civil Engineering Practice With a Commitment to a Sustainable Future*, Proceedings of the International Workshop on Sustainable Development Planning and Engineering Environment, Chinese Civil Engineering Society, Canadian Society for Civil Engineers, Beijing, 1994, pp. 29-41

138. Johnson, C. D. and Kramer, J. M., *Setting the Stage - An Assessment of the State of the Planet from a Sustainability Perspective*, Proceedings of the International Workshop on Sustainable Development Planning and Engineering Environment, Chinese Civil Engineering Society, Canadian Society for Civil Engineers, Beijing, 1994, pp. 10-20

139. Karan, F. A., *Infrastructure Maintenance Management System Development*, Journal of Professional Issues in Engineering, Vol. 115, No. 4, October 1989, pp. 422-433

140. Keating, M., *The Earth Summit's Agenda for Change: A Plain Language Version of Agenda 21 and the Other Rio Agreements*, Centre for Our Common Future, Geneva, 1993

141. Kelly, M., *Market Correction: Economic Incentives for Sustainable Development*, National Round Table on the Environment and the Economy, Ottawa, 1992

142. Kenworthy, J., and Newman, P., *Cities and Automobile Dependence: A Sourcebook*, Gower Technical, Australia, 1989

143. Khan, A. M., *Strategic Planning for Sustainable Transportation Development*, Proceedings of the 1995 Annual CSCE Conference, Canadian Society for Civil Engineers, 1995, pp. 593-602

144. Kibert, C. J., *Establishing Principles and a Model for Sustainable Construction*, Sustainable Construction, Proceedings of the First International Conference of CIB TG 16, International Council for Building Research, Center for Construction and Environment, University of Florida, Tampa, 1994, pp. 3-11

145. Knight, J., *Rebuilding Canada from the Underground Up*, Canadian Business Review, Canada, Summer 1992, pp. 35-37

146. Lamphere, P., *The Politics of Infrastructure Management*, Proceedings: Local Government Infrastructure Management, Urban Planning and Development Division, American Society of Civil Engineers, New York, 1986, pp. 11-14

147. Leach, D., and Wagstaff, H., *Future Employment and Technological Change*, Billing and Sons Ltd., Worcester, 1986

148. Leigland, J., *Selling Bonds Worldwide*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989

149. Leitman, J., and Rabinovitch, J., *Urban Planning in Curtiba*, Scientific American, March 1996, pp. 46-53

150. Lemer, A. C., and Gould, J. P., *Toward Infrastructure Improvement: An Agenda for Research*, Committee for an Infrastructure Technology Research Agenda, National Research Council, Washington, D. C., 1994

151. Lemer, A. C., and Grant, A. A., *In Our Own Backyard: Principles for Effective Improvement of the Nation's Infrastructure*, Committee on Infrastructure, National Research Council, Washington, D.C., 1993

152. Lemer, A. C., *Infrastructure Obsolescence and Design Service Life*, Journal of Infrastructure Systems, December 1996, pp. 153-161

153. Lemer, A. C., *We Cannot Afford Not to Have a National Infrastructure Policy*, Journal of American Planning Association, Volume 58, #3, pp. 362-366, 1992

154. Lester, V., Miller, T., Shapiro, C. and Whitman, R., *Infrastructure Needs: A Critical Review*, Three Studies on Infrastructure Needs and Financing, Division of Economic Development and Policy, Office of Economic Affairs, Office of Policy Development and Research, Washington, D. C., 1984

155. Lewis, D., *Infrastructure and Economic Growth*, Infrastructure and Competitiveness, John Deutsch Institute for the Study of Economic Policy, Industry Canada, Queen's University, Kingston, 1993, pp. 301-334

156. Liberal Party of Canada, *Creating Opportunity: The Liberal Plan for Canada*, Ottawa, 1993

157. MacNeill, J., *Strategies for Sustainable Economic Development*, Scientific American, September 1989, pp. 155-165

158. Malone, T. F., *The World After Rio*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp.25-32

159. Mandel, L. H., and Wilker, J. J., *Municipalities: The Defendants of the 90s*, Municipal World, Parts 1, 2 & 6, 1993

160. Marland, G., and Weinberg, M., *Longevity of Infrastructure*, Cities and their vital systems: Infrastructure Past, Present, and Future, National Academy of Engineering, Washington, D.C., 1988, pp. 312-332

161. Marshall Macklin Monaghan Limited, *Achieving Infrastructure Cost Efficiency/ Effectiveness through Alternative Planning Approaches*, Canada Mortgage and Housing Corporation, Ottawa, 1992

162. Marshall Macklin Monaghan Limited, Berridge Lewinberg Greenberg Ltd., Reic Ltd., *Making Choices: Alternative Development Standards*, Ontario Ministry of Housing and Ministry of Municipal Affairs, Toronto, 1994

163. Matzer, J., *Infrastructure : The State of the Art*, Capital Projects: New Strategies for Planning, Management, and Finance , Washington, D.C., 1989, p.3

164. McCracken, M. C., and Sonnen, C. A., *Infrastructure and the Canadian Economy: The Macroeconomic Impacts*, Infrastructure and Competitiveness, John Deutsch Institute for the Study of Economic Policy, Industry Canada, Queen's University, Kingston, 1993, pp. 123-170

165. McKay, H., *Introducing an Operations Management System*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989, pp. 115-120

166. McNeil, S., Sanford, K. L., and Tarr, J. A., *Crisis Perception and Policy Outcomes: Comparison Between Environmental and Infrastructure Crisis*, Journal of Infrastructure Systems, December 1995, pp. 195-202

167. Menniti, J. P., *Using Computers Effectively in Today's Civil Engineering Office*, Journal of Infrastructure Systems, October 1996, pp. 261-262

168. Moore, T., and Thorsnes, P., *The Transportation/Land Use Connection*, American Planning Association, Washington D.C., 1994

169. National Council on Public Works Improvement, *The Nation's Public Works, Defining the Issues: Report to the President and the Congress*, Washington, D. C., 1986

170. National Council on Public Works Improvement, *Fragile Foundations: A Report on America's Public Woks*, The Council, Washington, D.C., 1988

171. National Council on Public Works Improvement, *Emphasizing Better Maintenance*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989, pp. 201-205

172. Nelson, P. P., *Civil Infrastructure Systems: An Integrated Research Program*, National Science Foundation, Washington, D. C.

173. Netzer, D., *Do We Really Need a National Infrastructure Policy?*, Journal of American Planning Association, Volume 58, #2, pp. 139-143, 1992

174. Neumann, L. A., and O'Day, D. K., *Assessing Infrastructure Needs: The State of the Art*, Perspectives on Urban Infrastructure, National Research Council, Committee on National Urban Policy, Commission on Behavioral and Social Sciences and Education, National Academy Press, Washington, D.C., 1984, pp. 67-109

175. NRCC, *A Review of Canada's Physical Infrastructure*, National Research Council Canada, Ottawa, 1993

176. NRTEE, *Prosperity and Sustainable Development for Canada: Advice to the Prime Minister*, National Round Table on the Environment and the Economy, Ottawa, 1993

177. NRTEE, *Discussions on Decision Making Practices for Sustainable Development*, National Round Table on the Environment and the Economy, Ottawa, 1991

178. Oberlender, G. D., *Project Management for Engineering and Construction*, McGraw Hill, New York, 1993

179. ORTEE and NRTEE, *A Strategy for Sustainable Transportation in Ontario: Report of the Transportation and Climate Change Collaborative*, Ontario Round Table on Environment and Economy, National Round Table on the Environment and the Economy, Toronto, 1995

180. Parson, E. A, *The Transport Sector and Global Warming: Background Study for OTA Global Warming Report*, Kennedy School of Government, Cambridge, 1989

181. Parthum, C. A., *Environmental Challenge for Engineers*, Journal of Professional Issues in Engineering Education and Practice, pp. 19-20

182. Paul Theil Associates Limited, *Comparative Subdivision Servicing Study: Cost Analysis of New Techniques*, Housing and Urban Development Association of Canada, Toronto, 1979.

183. Payne, H. G., *Municipal Services: Repair or Replace?*, The Proceedings of the First Canadian Conference on Infrastructure, Edmonton, 1987, p.107

184. Perry, D. C., *Building the Public City: The Politics, Governance and Finance of Public Infrastructure*

185. Petersen, G. E., *Lagging Infrastructure Investments: Consequences for Economic Development*, The Urban Institute, Washington, D.C., 1989

186. Peterson, G. E, *Is Infrastructure Being Under-Supplied?*, Urban Land Institute, Washington, D.C., 1990

187. Peterson, G. E., *Historical Perspectives on Infrastructure Investment: How Did We Get Where We Are?*, The Urban Institute, Washington, D. C., 1991

188. Peterson, G. E., *Financing the Nation's Infrastructure Requirements*, Perspectives on Urban Infrastructure, National Research Council, Committee on National Urban Policy, Commission on Behavioral and Social Sciences and Education, National Academy Press, Washington, D.C., 1984, pp. 110-142

189. Poggemeyer, L. H., *New Frontiers in Civil Engineering: Infrastructure*, Journal of Professional Issues in Engineering, Vol. 115, No. 4, October 1989, pp. 393-196

190. Porter, D., *Regional Governance of Metropolitan Form: The Missing Link in Relating Land Use and Transportation*, Transportation, Urban Form, and the Environment, Irvine, 1990, pp.63-80

191. Porter, D. R., *Financing Infrastructure with Special Districts*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989

192. Portland Cement Association, *Investing In Our Future: A Challenge to Revitalize our most Valuable Public Assets; An Opportunity for Economic and Employment Growth.*, USA, 1992

193. Postner, H. H, *A Note on Infrastructure and Productivity*, Government and Competitiveness, School of Policy Studies, Queen's University, Kingston, 1993

194. Prendergast, J., *Engineering Sustainable Development*, Civil Engineering, October 1993, pp. 39-42

195. Rainer, G., *Understanding Infrastructure: A Guide for Architects and Planners*, New York, 1989

196. Rakhra, A. S., *Reinvesting In Infrastructure For Economic Growth*, Canada Mortgage and Housing Corporation, Ottawa, 1992

197. Regional Municipality of Ottawa-Carleton, *Alternative Development Standards: Proposals to Reduce Housing Costs*, Ottawa, 1992

198. Revay, S. G., *Value for Money - An Integrated Report*, The Revay Report, Volume 13, Number 1, February 1996

199. Ritchart, D. L., *Microcomputers as Tools for Infrastructure Management*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989, pp. 100-114

200. Roberts, D. V., *Sustainable Development - A Challenge for the Engineering Profession*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 44-61

201. Roberts, G. M., *Public Health Effects of Water, Air, and Land Pollution*, Proceedings of Public Works and Society, American Society of Civil Engineers, The Institution of Civil Engineers (UK), Florida, 1972, pp. 117-126

202. Rodi, S., *Infrastructure Management: A Geographic Information System Application*, The Proceedings of the First Canadian Conference on Infrastructure, Edmonton, 1987, p.99

203. Rondinelli, A., *Decentralizing Public Services in Developing Countries: Issues and Opportunities*, Journal of Social, Political and Economic Studies, Volume 14, #1, 1989

204. Ross, T., *Privatization of Facilities*, Capital Projects: New Strategies for Planning, Management, and Finance, Washington, D.C., 1989

205. Sanders, H. T., *Politics and Urban Public Facilities*, Perspectives on Urban Infrastructure, National Research Council, Committee on National Urban Policy, Commission on Behavioral and Social Sciences and Education, National Academy Press, Washington, D.C., 1984, pp. 143-177

206. Schofield, N., *The Role of Government*, Transport, the Environment and Sustainable Development, UK, 1993, pp.117-125

207. Seaden, G., *Economics of Innovation in the Construction Industry*, Journal of Infrastructure Systems, September 1996, pp. 103-107

208. Shaver, P. J., *Alternative Financing for Transportation Facilities*, University of Alberta, Edmonton, 1995

209. Siddiqui, Sadaf, and Mirza, M. S., *Canadian Municipal Infrastructure - The Present State*, Proceedings: 1st Transportation Specialty Conference, Volume 3b, 1996 Annual Conference, Canadian Society for Civil Engineers, Edmonton, 1996, pp. 519-530

210. Slack, E., *Financing Infrastructure: Evaluation of Existing Research and Information Gaps*, Enid Slack Consulting Inc., CMHC, Ottawa, 1996

211. Soberman, R. M., *Taking Stock: A Review of the Canada Infrastructure Works Program*, The Canada Infrastructure Works Office, Treasury Board Secretariat, Ottawa, 1996

212. Stretch, A. H., *The Changing Role of the Engineer in Infrastructure Delivery*, Proceedings: 1st Transportation Specialty Conference, Volume 3b, 1996 Annual Conference, Canadian Society for Civil Engineers, Edmonton, 1996, pp. 471-482

213. Swanson, E., *Putting Sustainable Development to Work: Implementation Through Law and Policy*, Alberta Environmental Law Center, 1994

214. TAC, *Briefing: A New Vision for Urban Transportation*, Transportation Association of Canada, Ottawa, 1993

215. TAC, *A New Vision for Urban Transportation*, The Transportation Association of Canada, Urban Transportation Council, 1992

216. Tarr, J. A., *The Evolution of the Urban Infrastructure in the Nineteenth and Twentieth Centuries*, Perspectives on Urban Infrastructure, National Research Council, Committee on National Urban Policy, Commission on Behavioral and Social Sciences and Education, National Academy Press, Washington, D.C., 1984, pp. 4-66

217. Tarr, J. A., *Patterns in the History of the Urban Infrastructure*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp. 247-251

218. Thom, D., *Engineering to Sustain the Environment*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 62-80

219. Touche Ross, MIT and Prudential-Bache Securities, *The Infrastructure Crisis*, Roundtable, 1983

220. Tullu, K. S., Rehabilitation, *Testing and Management of Concrete Bridges*, McGill University, Montreal, 1992

221. Urban Land Institute, *Project Infrastructure Development Handbook*, Washington D.C., 1989

222. Warszawski, A., *Strategic Planning in Construction Companies*, Journal of Construction Engineering and Management, June 196, pp. 133-140

223. Weiss, E. B., *Legal Dimensions of Global Change: A Proposed Research Agenda*, 1989

224. WEPSD, *Engineering for Sustainable Development*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 7-11

225. Weston, R. F., *Towards Understanding the Idea of Sustainable Development and Sustainable Development Implementation Guidelines for Engineers*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 40-43

226. WFEO, *Code of Environmental Ethics for Engineers*, The Role of Engineering in Sustainable Development, American Association of Engineering Societies, World Engineering Partnership for Sustainable Development, Washington, D. C., 1994, pp. 12-14

227. Williams, H. G., *Legislation Needed to Rehabilitate our Water and Sewer Infrastructure*, Infrastructure: Maintenance and Repair of Public Works, New York, 1984, pp. 82-85

228. Woodhull, J., *How Alternative Forms of Development can Reduce Traffic Congestion*, Sustainable Cities: Concepts and Strategies for Eco-City Development, Los Angeles, pp. 168-177

229. Wright, R. N., *National Goals for Construction Technology*, Journal of Infrastructure Systems, December 1995, pp. 193-194

230. Wright, D., *Educating Civil Engineers for Leadership Roles in Public Works*, Infrastructure: Maintenance and Repair of Public Works, New York, 1984, pp. 169-175

231. www.asce.org

232. www.fcm.ca

233. www.munisource.org

234. www.naco.org

235. www.pubworks.org

236. www.sustainable.doe.gov

237. www.wenet.org

238. Yao, J. T. P., *On Civil Infrastructure Systems and Engineering Education*, Journal of Infrastructure Systems, March 1996, pp. 1-3

239. Yoda, K., *Recycled Cement and Recycled Concrete in Japan*, Reuse of Demolition Waste, Proceedings of the Second International Symposium held by RILEM, Great Britain, 1988, pp. 527-536

240. Young, C. S., *Infrastructure: Local Government Role*, Infrastructure: Maintenance and Repair of Public Works, New York, 1984, pp. 21-26

241. Zeiss. C., *Setting Research Priorities and Perspectives for Urban Infrastructure Planning*, The Proceedings of the Second Canadian Conference on Infrastructure, Edmonton, 1989

242. Zimmerman, K. A. C., *Promoting Management Systems Within Organizations*, Infrastructure Planning and Management, Proceedings of Two Parallel Conferences, American Society of Civil Engineers, New York, 1993, pp. 16-20