An Independent Study
Commissioned by

RESIDENTIAL AND
CIVIL
CONSTRUCTION
ALLIANCE OF
ONTARIO

RCCAO

Constructing Ontario's Future

CELEBRATING **10 YEARS** OF
INFRASTRUCTURE ADVOCACY
2005-2015

Building Our Tomorrow: The Future of Ontario's Infrastructure

How the impact of megatrends and rise of new infrastructure will change the province (and Canada)

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RCCAO
25 North Rivermede Road, Unit 13, Vaughan, Ontario L4K 5V4
Andy Manahan, executive director
e manahan@rccao.com p 905-760-7777 w rccao.com

The Residential and Civil Construction Alliance of Ontario (RCCAO) is composed of management and labour groups that represent a wide spectrum of the Ontario construction industry. The RCCAO's goal is to work in co-operation with governments and related stakeholders to offer realistic solutions to a variety of challenges facing the construction industry and which also have wider societal benefits.

RCCAO has independently commissioned 35 reports on planning, procuring, financing, and building infrastructure, and we have submitted position papers to politicians and staff to help influence government decisions.

For more information on the RCCAO or to view copies of other studies and submissions, please visit **rccao.com**

RCCAO members include:

- Carpenters' Union
- Greater Toronto Sewer and Watermain Contractors Association
- Heavy Construction Association of Toronto
- International Union of Operating Engineers, Local 793
- International Union of Painters and Allied Trades, District Council 46
- Joint Residential Construction Association
- LiUNA Local 183
- Ontario Formwork Association
- Residential Carpentry Contractors Association
- Toronto and Area Road Builders Association

Building Our Tomorrow: The Future of Ontario's Infrastructure

How the impact of megatrends and rise of new infrastructure will change the province (and Canada)

An independent research study prepared for the Residential and Civil Construction Alliance of Ontario (RCCAO)

By
Michael Fenn,
former Ontario Deputy Minister
and founding CEO of Metrolinx

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AUTHOR AND ACKNOWLEDGEMENTS

Michael Fenn is a consultant and board director. Over the course of an extensive career in public service, he has been an Ontario Deputy Minister under three Premiers, municipal chief administrator in Hamilton and Burlington, and the founding CEO of both Metrolinx and the Mississauga Halton Local Health Integration Network (a regional health authority serving one million residents from Etobicoke to Georgetown).

Mr. Fenn is a board director of the $72-billion OMERS AC pension fund and with the Toronto Board of Education's realty arm, the Toronto Lands Corporation. His research projects in the past two years include: "Recycling Ontario's Assets: A New Framework for Managing Public Finances" for the Mowat Centre at the School of Public Policy at the University of Toronto; "Approaching an Inflection Point: Provincial-Municipal Relations in Ontario" (co-authored with André Côté) for the Institute of Municipal Finance and Governance, at the Munk School of Global Affairs, also at the University of Toronto; and, "Unlocking Ontario's Advantages: Building new infrastructure on the foundation of existing public assets" for the Residential and Civil Construction Alliance of Ontario (RCCAO).

Mr. Fenn wishes to acknowledge the support and advice of the RCCAO, especially Phil Rubinoff, chairman, and Andy Manahan, executive director, in the development of this project. Earlier RCCAO independent research has proved to be a solid foundation for this look into the future, including the February 2009 study by T. E. El-Diraby, T. Wolters and H. M. Osman, "Benchmarking Infrastructure Funding in Ontario: Towards Sustainable Policies."

Both Mr. Fenn and the RCCAO wish to make particular mention of the important contributions of senior futurist Richard Worzel. (His section can be found in Appendix A.) Mr. Worzel greatly improved the vision of this report through his many insightful and thought-provoking suggestions.

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The viewpoints expressed in this report are those of the author and not necessarily the views of the RCCAO, the reviewers and other contributors, nor of the organizations with which Mr. Fenn is associated. Any errors or shortcomings in the report are entirely the responsibility of the author.

"A thought which does not result in action is nothing much, and an action which does not proceed from thought is nothing at all." — French author Georges Bernanos

"Don't skate to the puck. Skate to where the puck is going to be." — Walter Gretzky, to his son Wayne

EXECUTIVE SUMMARY

The public debate about the need to invest in public infrastructure has reached the point of broad consensus in Canada and across the world. In the last Ontario budget, the provincial government committed to funding $130 billion over 10 years. Unfortunately, there is much less understanding of the need to build the right infrastructure in the long term, using the most sustainable and forward-looking financial instruments and tax policies.

Will our future look like the world of *The Jetsons* and *Disney's Tomorrowland*? Can the dynamism and modernism of city-states like Singapore or Dubai be scaled to a jurisdiction like Ontario? Can we avoid the white elephants of poor infrastructure planning (Montréal's Mirabel airport)? Can we benefit from foresight, as with Toronto's 1918 Prince Edward Viaduct – built to include Bloor-Danforth subway infrastructure used decades later?

How can Ontario's big public decisions about infrastructure ensure that we anticipate the future and promote greater prosperity and a better quality of life? Short-term considerations – current economic or fiscal conditions, electoral politics, localized concerns – can result in sub-optimal decisions, or the deferral of difficult but urgent needs.

This report identifies megatrends – major trends or movements – affecting our infrastructure decisions between now and 2030. It also draws upon the expertise of renowned Canadian futurist Richard Worzel who sheds some light on what's to come for Ontario (please see Appendix A). Among the megatrends we both believe will be key to those decisions are technological changes, globalization and demographic shifts.

THREE KEY FINDINGS

The report's analysis yields some surprising prospects:

- **Transportation:** This can give us faster and less congested trips, enabling long-distance commuting and dependable logistics. Broad-based acceptance of innovations – automated vehicle control, driver-assisted vehicles, road-pricing regimes, in-vehicle technology for distance-separation and collision-avoidance, expressway system-access controls, drone technology, vehicle-and-ride sharing, computer-aided logistics and dispatch, high-speed trains and a renaissance in water transport – will combine to revolutionize Ontario's transportation. In **rapid transit** and **public transit**, we will see complementary innovations. Platform-side doors, automated train control, and time-of-day and distance-sensitive, universally accepted, bank-linked, multi-purpose fare-media will increase throughput and reduce congestion, despite increasing passenger volumes. Fare-media will also be used for parking and convenience incidentals, like coffee and lottery tickets, and using incentives and disincentives to improve system performance. But as Grush and Niles point out in Appendix C, whether driver-assisted and automated cars will be a positive or negative development depends upon how they unfold, and the extent to which society acts pro-actively to plan and manage them.

- **Light, flexible and adaptable infrastructure:** With the convergence of miniaturization, pre-constructed components and new building materials, the infrastructure of tomorrow will include more light, flexible infrastructure. While some long-lived infrastructure will be designed to be more resilient to address climate change impacts, other infrastructure will need to be adaptable or have a shorter life expectancy and amortization period than traditional structures. For example, transportation infrastructure might have to be moved or reformatted before its planned end of life. In essence, greater flexibility will have to be incorporated into the design process through new, cost-effective materials. Similarly, different delivery models will be necessary due to factors such as evolving economic conditions, and changing demographics.

- **Health care:** This is a primary target for convergence of infrastructure, as Ontario aims to meet the evidence-based test of "right treatment, by the right provider, in the right place, at the right time, for the lowest cost to the taxpayer." Integration of health care delivery is the key. Our health care infrastructure investment and funding policies should anticipate, facilitate and support sound health policy choices. Technological and medical measures to maintain the elderly in their own homes and in retirement residences will expand dramatically, as the size of the elderly population balloons. But it also should mean less emphasis on "bricks-and-mortar" hospitals and more attention to community health facilities, both public and private. In the future, outside of under-serviced areas, Ontario might need to build or expand hospitals only for advanced treatments and research.

THREE RECOMMENDATIONS

At the outset of this project, Mr. Worzel indicated that the role of a futurist is not to make precise predictions about the future. Rather it is to identify trends that might shape the future and then to have the right framework to adapt our infrastructure. Thus, society and our governments need to respond more quickly and to think differently about infrastructure than we have in the past.

Above all, we need to have the right framework for making Ontario's infrastructure decisions. With this in mind, this report puts forward three broad recommendations to form a strategy on the future of infrastructure for Ontario (a more detailed list is found on Pages 90-92):

1. To determine how to build it right and get the best return on investment, this report recommends establishing a mechanism within government to establish a new, integrated decision-making structure for infrastructure decisions. It should begin by elevating the ministry division responsible for infrastructure to a full-scale **Policy Secretariat, headed by a Minister and Deputy Minister**. The Policy Secretariat's mandate would include support for the work of an ongoing "Ontario Future Council" made up of a cross-section of Ontario's thought-leaders and decision-makers from the worlds of business, labour, government and academia, traditional and social media, non-profit organizations and broader civil society. The Future Council would be led by an executive committee of distinguished Ontarians that would advise on how to take a future-oriented approach to planning and building infrastructure in Ontario, with authoritative recommendations focusing on the policy and performance management issues.

2. Through research grants, the governments of Ontario and Canada should engage post-secondary and health care scholars and leading thinkers from the various sectors of Ontario society to address infrastructure issues. A suite of **infrastructure innovation grant funds** could promote future-oriented infrastructure investment and evidence-based benchmarking. In particular, these funds could promote collaboration between municipalities (and Aboriginal communities) and private-sector firms to address identified local challenges.

3. Appoint a **Royal Commission on Ontario's Future**, with a particular focus on the role that infrastructure can play in creating a prosperous, productive and equitable society, beginning with a broad, **future-oriented economic development and infrastructure strategy**.

BACKGROUND

The Residential and Civil Construction Alliance of Ontario (RCCAO) regularly commissions independent research in fields of interest or concern to its members and to those that they represent. Infrastructure, in all its aspects, is an important part of RCCAO's research agenda.

The need for infrastructure investment, both in Ontario and globally, has somewhat belatedly come to be acknowledged across the political spectrum and in all parts of the public and private sectors. That is good news, but it is only a start. That we should act – and that action is long overdue – seems to be universally accepted. But where to act, what to build and how to finance it remain important issues.

Ironically, not adequately addressing Ontario's infrastructure gap in the past may turn out to be a great opportunity. The post-war economic miracles of Germany, Japan and South Korea show that skipping a generation of infrastructure and technology can enable a society to make a great leap forward in productivity, standards of living and even social equity.

Built properly, infrastructure lasts a long time. Good infrastructure decisions can serve us well, economically, socially and environmentally. Poor or shortsighted infrastructure decisions will burden us and those who follow for generations.

This report was first proposed by Phil Rubinoff, chairman of the RCCAO. RCCAO and other thought-leaders have helped to stimulate the current public debate over infrastructure investment across Ontario and elsewhere. Reflecting on the success of those initiatives, the RCCAO observed that emerging trends and their impacts would have significant implications for the nature of future infrastructure in Ontario. There is a corollary: new infrastructure will affect the future of work and society in Ontario, particularly for those who design, build, operate, and use civil and economic infrastructure.

This report responds to those twin challenges. It conducts a forward-looking analysis of the infrastructure that we will likely see, and that we may need in the next generation in Ontario and Canada, particularly in our cities and urban regions.

Among the global thought-leaders in the infrastructure field has been the renowned magazine *The Economist*, notably in a series written by researcher and writer Ryan Avent. Avent canvassed academic scholars and other leading thinkers from around the world and in a variety of fields. He interviewed them about global trends and their implications, particularly for the future of work. His thought-provoking "Special Report on the World Economy" appeared in the October 2014 edition of *The Economist*, entitled "The Third Great Wave."[1] That special report addressed a wide range of often inter-related emerging economic and societal trends, several of which are important for the focus of this report.

Earlier RCCAO independent research has proved to be a solid foundation for this report's look into the future, including the RCCAO's February 2009 study by T. E. El-Diraby, T. Wolters and H. M. Osman, "Benchmarking

Infrastructure Funding in Ontario: Towards Sustainable Policies."[2] Jurisdictions like New South Wales (Australia), Singapore and the United States (Environmental Protection Agency) point the way to evidence-supported decisions about infrastructure and practical performance measurement of needs and outcomes.

A meta-analysis of infrastructure

The Economist's October 2014 analysis gave rise to the proposal that a meta-analysis research project might help to prepare Ontario for the infrastructure challenges that lie ahead. Drawing from medical research practice, meta-analysis can be thought of as conducting research about previous research. Simply stated, the goal of meta-analysis is to distill an overall conclusion from a wealth of research material. It aims to identify evidence-supported, best-practice courses of action or treatments, based on a "balance of probabilities"; it is drawn from the available evidence, produced by recognized researchers and research organizations. In looking at infrastructure and the trends that affect it, our intention here is not to duplicate work that has been done before, but to profit from it and to try to synthesize it.

This report looks at the many trends and innovations that might influence the nature, pace, financing and construction of the infrastructure of the future. Many experts have commented on the impact of specific trends on infrastructure. Conversely, new types of infrastructure will have an impact on the people, communities and society that they serve. In some cases, the research findings of experts will echo one another; in other instances, they will appear to diverge in their conclusions or their recommendations. Even these differences of opinion, however, can be thought-provoking and lead to new insights.

In keeping with the meta-analysis approach, this report has collected ideas from a cross-section of disparate sources. We have attempted to identify, distill and highlight prevailing views and conclusions. In meta-analysis, rejecting some findings as outliers is part of the analysis methodology (much like dropping the vote of the East German judge in Olympic figure skating!).

We are also conscious of the risks of group think and conventional wisdom, which can often miss emerging disruptive innovations – and recent decades offer many examples. However, by looking to the work of those who have a track record of accurately foreseeing trends and their impacts, we have tried to mitigate this risk.

In addition, this report endeavours to suggest ways in which governments and their stakeholders can approach the future of infrastructure with flexibility and openness, in a spirit of innovation and overcoming short-term thinking or resistance to unwelcome change. We need to avoid the sins of the past, including the clearly evident neglect of the past several decades, which has left us with a huge infrastructure deficit. This report hopes to remind us of the great potential benefits that foresighted decisions on infrastructure promise for all of us.

To say that this has proved to be a complex and uncertain task is an understatement.

The future is a vast and uncharted country. The sheer scope of this investigation has meant that many topics of importance and interest could not be given the profile and analysis that they deserve. This report contains a very extensive Endnotes section, which directs the reader to the research and informed opinions that underpin its observations and conclusions. Serious readers are encouraged to explore these sources for a more fulsome explanation of issues of particular interest.

The relationship among often-conflicting policy goals is complex. The future of employment and the role of the public, private and non-profit sectors are interwoven and dynamic – and sometimes riven with ideology. The nature of future infrastructure, especially looking forward several decades, is nebulous and speculative at best. Our age has no Oracle of Delphi.

But avoiding thinking about the future is even worse. One thing is certain: assuming Ontario society and its various governments can continue into the future by following the paths of the past is the route to unpleasant surprises,

with expensive and embarrassing policy failures. Even in a fog, the best course is to look through the windshield, not the rear-view mirror.

What do we mean by infrastructure?

Infrastructure is made up of the physical plant and distribution systems that make modern society and economic activity possible. It ensures that labour, capital, materials and information can be deployed in ways that are productive and serve society's needs. Good infrastructure is an essential ingredient in economic growth and prosperity. It is critical to both private sector and public sector productivity. But only if we build the right infrastructure, reflecting evidence and our anticipated future, not political expediency or merely repeating the past.

A lack of good infrastructure – and deteriorating infrastructure – can diminish productive capacity and the efficiency of markets for goods and services, resulting in higher costs and poorer price competitiveness. There is, therefore, an implicit "rate of return" (ROR) on infrastructure investment, which goes beyond a simple financial "return on investment" (ROI) test. ROR can be defined either by the increases in productivity that it enables or by the costs that its absence imposes. Part of our meta-analysis will be to try to provide the ROR for different infrastructure needs, in order to avoid the classic, simplistic dismissal of infrastructure investments as "too expensive" or the corresponding assumption that a big investment is the best investment. It is true that infrastructure investing is often expensive. The more relevant question is whether it is more cost-effective to have it, than not to have it.

The term "infrastructure" covers a wide variety of diverse systems and networks. These are governed by differing physical characteristics, uses, ownership patterns and lifecycles. This report also makes the case that, in the future, our conventional understanding of infrastructure will change in ways not seen since the advent of steam, the electricity grid and the automobile.

To add to the complexity of this analysis, various types of infrastructure have different relationships to the society and economy that they serve and support. Some is used to transport goods and services to and from centres of production or economic activity. Other infrastructure is used to deliver people and business-support services to centres of employment or training. Some is used to support a region's or a community's quality of life, by underpinning safe, healthy, and sustainable living conditions for people and enterprises.

In RCCAO's earlier publication "Investing in Ontario's Infrastructure," public investment in infrastructure was defined as: "… including roads and highways, rapid transit, water supply and wastewater treatment, rail, aviation, water transportation, as well as electricity and broadband infrastructure …."[3] In its subsequent report on the subject, RCCAO expanded the definition to include a wider range of social and technological infrastructure,[4] to which we could further add infrastructure associated with waste disposal and resource recovery, without even considering important private-sector infrastructure. We will broaden that list to include infrastructure of the future. In our research scope, we have included infrastructure investments that are often overlooked or neglected as politically unpopular. All public infrastructure requires long-term investments that have social and economic effects.

While we briefly summarize the range of Ontario's infrastructure in this section, a more detailed summary of infrastructure is outlined in Appendix B. In it, 11 major types of civil and public infrastructure have been grouped into five broad categories: transportation; energy and telecommunications; environmental; social infrastructure; and, government business enterprises and other public assets. In several instances, we have added a brief comment on potential future directions. Our list of infrastructure focuses on civil infrastructure and public assets, which serve the whole community or broad categories of users. The focus of this report does not generally include infrastructure designed to serve a business enterprise or for commercial marketing, although there may be some overlap (e.g., privately owned natural gas retail distribution networks, or the private bus fleets serving school boards or operated by commercial intercity bus lines).

Trends changing infrastructure needs

As noted above, the importance of infrastructure to Ontario's future is now widely accepted, across the political spectrum. The need to invest in infrastructure of all kinds – both to make up for past neglect and to build the next generation of infrastructure – has finally reached the top of the public agenda. The calls for immediate action on infrastructure are widespread, echoing those across North America and around the world. For the most part, we have not invested enough to maintain existing infrastructure, much less expand it or build new capacity.[5,6] The low levels of interest rates now make such investments attractive from a ROR perspective, both to the public sector and to private sector investors and pension plans interested in P3s.

History has taught us, however, that widespread consensus and a sense of urgency can lead to inadequate planning and ill-considered choices. The imperative to build infrastructure should not be considered primarily in terms of reasonable or affordable levels of expenditure, or the impact on regions or employment. In the infrastructure-building frenzy in China and Japan, there are examples of new towns in the "middle of nowhere," "roads to nowhere" and seaports in tiny harbours. North America is not immune, as Sarah Palin's famous bridge-to-nowhere in Alaska demonstrated.[7] As noted above, the societal and governmental test should be long-term ROR. In making that ROR determination, attention to longer-term horizons and emerging trends can empower us to make prudent decisions now, the fruit of which may only be enjoyed much later in the future. In that regard, it is like navigating through unknown territory by aiming for distant landmarks, then staying on course.

It is equally important, however, both to sustain public support for an expensive, ambitious infrastructure investment agenda and to respond realistically to political mandates of short horizon. This report will not meet its goals if it cannot frame the future of infrastructure discussion in terms that will be relevant to today and make a compelling case for being concerned about tomorrow.

Looking forward by looking back

One of the best ways to remind us of the importance of anticipating change, and not simply projecting the past into the future, is to consider the pace of change in the last few decades. Few would dispute the accelerating rate of change in Ontario society. One needs only to reflect on the conditions that prevailed in recent memory to understand the scope and scale of those changes.

A few reminders tell the story:

- Less than two decades ago, only 11 per cent of the residents of the developed world used the Internet; now the figure is 77 per cent, exceeding 85 per cent for Canada, the U.S., Japan and many northern European countries, and a remarkable 46 per cent in China and about 30 per cent people in India. In 1997, the music and movie industries made much of their fortunes selling albums on CDs and renting movies on tapes and DVDs, which had completely displaced modern post-vinyl innovations like eight-track, Beta and VHS; royalties were a primary source of income for musicians and composers; the iPod, the iPad and music file-sharing did not exist; Blockbuster was a solid investment, but value of a share of Apple common stock had declined to US$13; in 2000, the majority of television screens were still small, bulky, blurry cathode tubes.

- In the latter part of the 20th century, express passenger trains struggled to achieve speeds of 80 km/hour; in most of North America, they still do; by contrast, in Japan, China and Western Europe, scheduled-service daily passenger trains now routinely quadruple that speed; in 1997, toll roads required toll takers in toll plazas.

- In 1998, Ontario-based investors launched the BlackBerry, which grew to command 43 per cent of the world market for smartphones, including customers like the current president of the United States; at the turn of the Millennium, neither Facebook nor Twitter existed, and Google was a start-up with a 2004 IPO share price of US$85 (a $10,000 investment then would have earned you $139,000 today). Today, Apple

is the world's most valuable company, and Google is third, but with far fewer employees than many traditional large commercial, industrial and public sector organizations.

- The famous August 2003 power blackout highlighted the vulnerability of Ontario's electrical power system and the brownout limits on its generating and transmission capacity, contributing to electoral defeat for then-Premier Ernie Eves. Today, Ontario's nuclear energy generation has absorbed the loss of coal-fired plants, while Bruce Power is looking to sell surplus power to the U.S. At the turn of the 21st century, climate-change impacts were a theoretical concern, with many skeptics; the Indian Ocean and Japanese tsunamis, Hurricane Katrina and Super Storm Sandy had yet to imprint on the public mind the vulnerability of public infrastructure during extreme weather events.
- Buoyed by the coalition triumph of the first Gulf War, future-oriented discussions at the turn of the Millennium revolved around an ultimately largely illusionary concern over Y2K, but rarely mentioned the future impact of global terrorism; yet 9/11 was only 21 months away, with the resulting vast public infrastructure expenditures in fields like airport, law-enforcement and security infrastructure.

Similar stories could be told about the unforeseen leap in the Greater Toronto and Hamilton Area's (GTHA) housing prices and the associated high levels of household mortgage debt; the efficiency and success of hybrid cars; the growth of online learning and commerce; the disruptive, almost devastating changes in the business of media and journalism as a result of the Internet, social media and cellphone cameras; the post-SARS awareness of the risks of global contagion; the roles of DNA, CCTV and forensics in the criminal justice system; and so on.

The bottom line is that many of our conventional assumptions and established practices, even those that seem contemporary, can be swept away in a very short period of time. We have many recent examples of the folly of "driving forward but looking backwards."

Four cautionary tales about infrastructure investment

We do have some interesting Ontario-based experience in the importance of paying attention to future trends before making major investments in public networks and facilities. There are lessons to be learned from the following four examples, as we plan our own, future-oriented investments in infrastructure:

1 Bridge building

In 1918, Toronto was suffering through Canada's fifth devastating year of the First World War. With an eye to the future, the growing municipality decided to build a monumental bridge to connect the city's great east-west thoroughfare, Bloor Street, with the East York bungalows and Scarborough manufacturing jobs that would welcome returning veterans. Immortalized in Michael Ondaatje's novel *The Skin of the Lion* and named after the dashing young Prince who would one day be King, the Bloor Viaduct was designed with a leap-of-faith addition. Reflecting infrastructure innovations in London, Paris and New York, and at modest additional cost, civic officials and their engineers strung below the bridge's deck the iron superstructure for an east-west subway line – which didn't exist and wasn't planned.

Economic recession followed the war, the dashing Prince abdicated, and the automobile and later the freeway displaced public transit on the public infrastructure agenda. Had that infrastructure investment been misdirected or a waste? A half-century later, the Bloor-Danforth subway opened – a project made much more affordable because subway trains ran along that long-forgotten iron infrastructure below the Viaduct.

This is not only a wonderful example of foresighted planning, but illustrates one of the key difficulties of making clearly thought-out investments in infrastructure: Today's infrastructure seems horrendously expensive, but yesterday's investments look like incredible bargains.

❷ Custodial health institutions

At the beginning of the 20th century, the scourges of tuberculosis, mental illness and developmental handicaps motivated governments to build large, often rustic, institutional accommodation for those receiving medical treatment and rehabilitation that required long-term institutionalization. These practices continued on a trajectory driven by past practice and institutional momentum, despite growing evidence that community-based treatment and pharmaceutical advances were more efficacious. In the case of tuberculosis and some mental illnesses, advances in treatment methods soon made those facilities largely irrelevant.

It proved difficult, however, to find practical ways to shift public health expenditure priorities in a timely fashion: from bricks-and-mortar solutions to community-based treatments and therapies; from capital programs to operating budgets; and from old health priorities to new health priorities. Looking to the future, will hospitals and universities do any better at making the same shift from bricks-and-mortar infrastructure to new, more cost-effective delivery models and research methods? Or will we be stuck, building monuments to the past and to past practices? Do conventional budgeting practices and philanthropy penalize such innovation and adaptability? Our future will be different. Therefore, cost-effective infrastructure should be different, and look different, from past solutions.

❸ Public housing

After the Second World War, the governments of Canada, Ontario and Toronto decided that something needed to be done to provide healthy, affordable housing for the economically disadvantaged, including the waves of new immigrants arriving in Toronto. In the custom of the era, they deferred to the experience of the U. K. and the U. S. They moved away from the post-war program of subsidized home ownership for returning veterans, to an affordable rental-housing policy. Public housing, a forerunner and subset of social housing and rent supplement programs, aimed to take the housing decision out of the hands of the working poor and the disadvantaged. Governments embraced

a model that would accommodate the poor in model neighbourhoods designed, located and built at public expense, and subsidized on an ongoing basis. In 1949, the first of these large-scale public housing projects opened – Regent Park, in Toronto. It displaced what *Cabbagetown* author Hugh Garner called the "worst Anglo-Saxon slum in North America."

In later years, socially progressive and cost-conscious governments refined the emphasis of public housing (as distinct from other types of social housing) away from a broad clientele that included the working poor to restrict public housing projects to those on public assistance, such as young, single mothers or recently arrived immigrants unable to find employment. Even as late as the 1970s, civic officials proudly pointed to vast concentrations of public housing, such as North York's Jane and Finch community.

Within a decade, however, from Cabrini flats in Chicago to "Council flats" in the U.K., public housing was being demolished or sold off (to tenants) as an expensive, failed experiment in social engineering. As if to punctuate the cost of good intensions but weak foresight, the multi-million dollar debts associated with Canada's public housing projects continued to be amortized on the books of the Canada Mortgage and Housing Corporation and its provincial counterparts. Do those social and public housing real estate assets, numbering more than 250,000 often well-located public housing and social housing units, have a future as social infrastructure or recyclable public assets? Or will they be simply an ongoing rehabilitation drain on the public purse?

4 Expressways and Subways

In 1971, the Ontario government decided that intra-urban freeways were not the wave of the future as previously imagined. Indeed, they were seen as destructive of established urban neighbourhoods. The long-promised extension of Toronto's Spadina Expressway (initially, south of Lawrence Avenue to downtown) was killed by Premier William Davis, coupled with a promise of renewed investment in rapid transit along Eglinton Avenue. Subway work proceeded, and it was joined with other proposals for rapid transit, including serving Toronto's growing North York neighbourhoods.

The deteriorating fiscal environment in Ontario and the costly way in which rapid transit was being built combined to force cutbacks and priority setting in the mid-1990s. The decision was made to proceed with the Sheppard subway line in North York and to abandon the Eglinton subway line. Thus, the under-construction Eglinton subway tunnel was filled in, and the multi-million dollar costs were written off. The project's innovative Canadian-manufactured tunnelling equipment was sold off at fire-sale prices, ironically to support an ambitious, cost-effective Spanish urban rapid-transit program. Ultimately, after the creation of the Metrolinx regional transportation authority, the decision was reversed and Eglinton is being excavated afresh, at today's higher prices, but using light-rail technology.

The Eglinton subway contains another lesson: political agendas too often interfere with clear thinking when it comes to infrastructure, a lesson that the City of Toronto's subsequent ambivalence in major road and transit decisions clearly illustrates.

What questions should we ask?

When it comes to infrastructure, the cost and impact of both good decisions and bad decisions are enormously magnified. In addition to the traditional questions about public expenditures on public infrastructure, the ongoing public debate about investing in infrastructure needs to consider some new and fundamental questions.

- What new forms of infrastructure will emerge and which will be obsolescent?
- Can new technologies render some major infrastructure unnecessary, or open the door to more modest solutions?
- How will major societal and economic trends influence the kind of infrastructure we will need?
- How will these trends change the economy, ecology and society that infrastructure must support?

- What will be the effects on labour and business – especially on those who will design, build, operate and use infrastructure in tomorrow's changing environment?
- Above all, what is our societal rate of return on our prospective investments in infrastructure?

This report aims to assist decision-makers – and citizens – with these important decisions, by providing a context within which to weigh their options.

What do the researchers and forecasters say?

Those who think about the future and the impact of megatrends on our future are careful to make the distinction between predicting and offering prospects, possibilities and options. If we are going to use influential trends as our filter, in order to project the future of infrastructure, what are those trends and where do we find them described? To answer these questions, we have identified several, somewhat differing perspectives, from which we will identify the trends to watch and against which we can evaluate the impact on infrastructure.

Richard Worzel, C.F.A.

It is also important to look beyond leading corporate entities and commercial consulting practices, to hear the futurists. As mentioned earlier, a good futurist does not predict the future, but offers prospects and possibilities. Internationally recognized Toronto-based futurist Richard Worzel wrote two bestsellers before the Millennium: *Facing Our Future: The Seven Forces Revolutionizing Our Lives* (1994),[8] and *The Next Twenty Years of Your Life* (1997). [9] Read today, with the benefit of hindsight, both of these works are surprisingly clear-sighted. Since Worzel's advice proved prescient in the past, the text of this report benefits directly from his observations about today's challenging effort to anticipate the future of infrastructure and its impact on society and work. **His commentary can be found in Appendix A.**

Other insights into megatrends and their impacts

In looking to other sources for insight into the future of infrastructure, the economy and society, we begin with technological change and the pace of technological change. In our generation, the terms "future" and "technology" have almost become interchangeable. While the future of infrastructure involves much more than just technology, it makes sense to begin our analysis there.

Grush Niles Associates

Bern Grush and John Niles are transportation specialists with unique insights into human behaviour regarding personal and public transportation, vehicle ownership and vehicle sharing. Their firm, Grush Niles Associates, is known for interfacing with many of the thought leaders in this world of new mobility. In Appendix C, they offer a number of provocative and intriguing ideas for anticipating and managing the transportation infrastructure and urban designs of the future.

(For more information on the next eight items, please click here: http://rccao.com/news/files/sept-appendix-D.pdf)

The Institute of Electrical and Electronics Engineers

In its landmark report on the impact of technology by 2022, the world's largest professional association for the advancement of technology, the 400,000-member Institute of Electrical and Electronics Engineers (IEEE) identified some 23 technologies to watch and provided a glimpse into the future.[10] Our analysis of the future of infrastructure considered the implications of the IEEE projections for Ontario, as technology will obviously be a key driver of social, economic and infrastructure change in the near future.

The Boston Consulting Group

Another source of insight into the trends that will affect our future comes from the well-respected global business strategy firm, Boston Consulting Group (BCG). While understandably more focused on the global economic future, including business risk and business opportunities, BCG identified some 50 trends that will change our economy and consumer society.[11] They group their findings under what might be termed megatrends: demographic trends, consumer trends, economic trends and, of course, technology trends.

McKinsey & Co.

Another business strategy consulting firm with global reach and a reputation for excellence in business strategy is McKinsey & Co. Three of its preeminent researchers produced a book that analyzes how several global forces are shaping, or will shape, the trends that we are analyzing in this report. In *No Ordinary Disruption: The Four Global Forces Breaking All the Trends*, the four overarching "global forces" are described:[12]

1. Urbanization
2. Pace of technological change
3. Demographics (aging and immigration)
4. Globalization and connectivity

Impact of new infrastructure on work and business

We need to look at ways in which new infrastructure may shape the nature of work, business, education, training and regulation. This report will give a special focus on those who are engaged in the design, financing, construction, operation and use of civil and economic infrastructure, including the housing market.

"The Third Great Wave" uncovered some very interesting but disturbing trends in areas such as the distribution of wealth and gainful employment in the society of the near future, based on skill-level and field of economic activity. (Some of the findings about capital accumulation and income inequality have echoes of popular French economist Thomas Piketty's recent bestseller *Capital in the Twenty-First Century*.[13])

Each of these trends has a direct link to the nature, demands and effects of infrastructure. "The Third Great Wave" extended its analysis to:

- The impact of these trends on urban settlement patterns and the cost of housing;[14]
- Variable patterns of employment and unemployment, by sector, by skill level and by region;
- When (and if) to use labour-substituting technology and its effect on productivity;
- The impact of industry-based and trades-based regulation on expanded employment;
- The globalization of supply chains and markets (and the associated logistics infrastructure) for even the smallest of enterprises; and,
- The prospects of all of these impacts for social unrest, immigration/emigration and decline in social cohesion, and the unpredictable political implications of all of them.

World Economic Forum

For the 2015 World Economic Forum, a consortium was commissioned to prepare an outline of global risks and major trends. This 10th edition of the global risk assessment was prepared by the Marsh and McLennan Companies and the Zurich Insurance Group, with the academic advisers from the National University of Singapore, Oxford University (Oxford Martin School) and the University of Pennsylvania's Wharton Risk Management and Decision Processes Center.[15]

In addition to identifying some 28 global economic, environmental, geo-political, societal and technological risks, the forwarding-looking assessment cited a baker's dozen high-level megatrends that would influence the world economy and affect the identified risks. These are:

1. Aging population
2. Climate change
3. Environmental degradation
4. Growing middle class in emerging economies
5. Increasing national sentiment
6. Increasing polarization of societies
7. Rise of chronic diseases
8. Rise of hyperconnectivity
9. Rising geographic mobility
10. Rising income disparity
11. Shifts in power
12. Urbanization
13. Weakening of international governance

Frost & Sullivan

Another global trends forecasting firm, Frost & Sullivan, prepared an intriguing, alternative list of megatrends.[16] Its list has a number of findings in common with the foregoing, but also with some new or differing insights. Frost & Sullivan's list of megatrends is summarized under these 11 headings:

1. Urbanization – City as a Customer
2. Smart is the New Green
3. Social Trends: Generation Y, Middle Bulge, "Sheconomy," Geosocialization
4. Connectivity and Convergence
5. Bricks and Clicks
6. Innovating to Zero
7. New Business Models: Value for Many
8. Economy: Beyond BRIC – The Next Game Changers
9. Future Infrastructure Development
10. Health, Wellness and Well Being
11. Future of Energy Future of Mobility[17]

Siemens

The global industrial and engineering giant Siemens produces a magazine focused on practical applications of new thinking around the world, with particular application to infrastructure in its broadest context. The fall 2013 edition of the magazine was particularly focused on the impact of trends on the future of infrastructure.[18]

Ontario Centres of Excellence

It is also important to look closer to home, for perspective on the innovations and trends that will influence the future of the Ontario economy and society. The Ontario Centres of Excellence (OCE) is a government-supported, separately incorporated collaboration among business, government, academic

research and entrepreneurs. Its stated mission is "accelerating innovation through game-changing research leading to successful commercialization and vibrant collaboration between industry and academia, launching the next generation of products and jobs."[19]

From across Ontario, it targets four sectors: (1) Advanced Health Technologies; (2) Advanced Manufacturing; (3) Information, Communications and Digital Media; and (4) Energy and the Environment.

While we have referenced the high-level trends that will affect infrastructure and the society and economy, it is useful to seek out practical applications and examples of innovation. The OCE provides an interesting, ground level window onto the potential impact of megatrends on infrastructure, right here in Ontario.[20] It is summarized in Appendix D.

What are the infrastructure implications of these megatrends?

The Economist's "The Third Great Wave" identified several major trends that are likely to significantly affect Ontario in the next 20 years. Some of these trends are global, while others are more indigenous.

It is always necessary to employ restraint and humility in making future projections, reflecting the fact that few would have predicted the course of the last quarter century. But it is possible to address the medium-term future with more confidence. A frame of reference might be the Ontario of 2030, which for policy-makers, roughly represents four electoral terms at all three levels of government.

We also need to engage in informed, evidence-based projections on the ways in which those broad trends might specifically influence the nature of the infrastructure needed to support the activities of that emerging Ontario society and economy. This would include consideration of policy and fiscal tools and planning processes that might advance good infrastructure decisions.

Societies and economies must be adaptive and responsive to change if they are to evolve progressively and prosper. To do so, we must adopt and adapt measures to discourage sub-optimal, inefficient or uneconomic fiscal and policy choices – a poor rate of return. For infrastructure planning and projects, this includes ways to overcome or mitigate predictable resistance to change or defence of status-quo privileges and entitlements, and even nostalgia and so-called NIMBY/BANANA impulses.[21] Legendary General Electric CEO Jack Welch best summarizes the risky implications of the knee-jerk, NIMBY response: "If the rate of change on the outside exceeds the rate of change on the inside, the end is near." Others would cite Darwin: "It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change."

What are the 'Big Six' megatrends that will affect infrastructure?

Based on our research and analysis, we have concluded that there are several major trends that will affect infrastructure and infrastructure decisions through to the year 2030 and beyond. While various analysts (including some cited here) have identified different trends or suggested more or fewer trends, the report finds that there are six megatrends particularly worth watching, for their impact on infrastructure and correspondingly, for infrastructure's impact on society and the economy.

1 Technological trends and the pace of technological change

Infrastructure is, at its heart, technology. As a result, technology trends will most conspicuously affect infrastructure. Recent trends in technology in all fields have taught us a common lesson: many of our conventional assumptions and established practices can be swept away in a very short period of time by the advance of new technology – and the public's embrace of it. The exponential increase in the pace of technology-impelled growth in some fields reminds us of the parable about doubling the number of grains of rice on each square of the Emperor's chessboard. Or to quote, *The Economist*: "Exponential growth … looks negligible until it suddenly becomes unmanageable."[22]

In its landmark report on the impact of technology by 2022, the world's largest technical professional association for the advancement of technology, the 400,000-member Institute of Electrical and Electronics Engineers (IEEE) identified some 23 technologies to watch and provided a glimpse into that future.[23] Our analysis of the future of infrastructure has considered the implications of the IEEE projections for Ontario, as technology will obviously be a key driver of social, economic and infrastructure change in the near future.

As "The Third Great Wave" succinctly concludes:

> "Technologies are tools without an agenda of their own, but their influence on society is never neutral. They blindly sweep aside the livelihoods of some people and enrich others. Politics must craft rules and institutions that harness technology to suit society's values and vision of itself."[24]

As noted earlier, technology could also significantly alter the nature of the social infrastructure we use to support a variety of social functions. Despite the rising demand for health care and education, both domestically and globally, will we still need the expensive bricks-and-mortar facilities that we traditionally use to deliver these programs, and the bureaucratic oversight they inevitably entail? Social infrastructure – health, education, custodial facilities, housing for the elderly – may see declines similar to those we have already seen in other fields, when responding to similar trends.

2 Urbanization, globalization and connectivity trends

In their new book, *No Ordinary Disruption: The Four Forces Breaking All the Trends*, McKinsey analysts include urbanization as one of the four great forces that will affect all of our lives in the future.[25]

Perhaps the greatest crossover between the broader societal and economic trends and the deployment of the infrastructure of the future comes in relation to transportation and accommodation of workers. "The Third Great Wave" summarizes the relationship in these words …

> "Having workers in the right places is critically important to generating more and better jobs. In both the rich and the emerging world unmet demand for housing is a significant constraint on growth … In rich countries restrictions on the supply of housing can be … pernicious. In economically dynamic places such as New York and London the shortage of housing is a serious constraint on growth in output and highly paid jobs. Inadequate investment in infrastructure exacerbates the problem. As roads and trains become more crowded, residents grow weary of agreeing to new developments, and so it goes on."[26]

Advances in "intelligent" transportation technology will change the face and the future of our cities and neighbourhoods, and the transportation and energy infrastructure that serves them.

Consider the infrastructure impacts of emerging technologies:

1. Driverless vehicles;[27]
2. Swedish-inspired road fatality reduction programs;[28]
3. Fully automated transit systems with generic, world-standard designs and equipment;
4. Re-engineered road intersections, cycling, pedestrian/parking arrangements;
5. More efficient and flexible modes of local public transit, school transportation and inter-urban trains;
6. Mobility hubs, like Madrid's *intercambiadores*;[29]
7. Widespread and more efficient mobility-assisting transportation designs;
8. Commercial use of drones and localized logistics for Internet-based goods-delivery fulfilment;
9. Very low energy-consumption vehicles and long-charge electric cars; and,
10. Entirely new types of personal vehicles, business vehicles and transit systems, addressing the issues of "the first/last 400 metres," customization of routing, urban market business-support vehicles, multi-modal connectivity, inter-urban transit and so on.

These will combine to alter the look of the street-level infrastructure in our suburbs, our urban cores and across our countryside.

Globalization trends will remind us that neither Ontario nor North America is an island. The growth of the middle-class in the once seemingly far-off lands of China, South Asia, Indonesia and Brazil and a new round of free-trade agreements, will change our markets, our patterns of commodity production and distribution, and even the demands on our educational and health systems. Correspondingly, commercial, environmental and political developments that were once safely on the other side of the world will increasingly affect our daily lives, much as the revolution in consumer products and durable goods manufacturing has altered North America's relationships with Asia over the past three decades.

3 Social and demographic trends

As demographers have pointed out since the Baby Boom generation learned to walk, Ontario's patterns of social demands (and related infrastructure demands) can be tracked closely to the annual aging of the post-war demographic cohort. As elementary and secondary schools built decades ago for Boomers (and retained for their "2.5 children") progressively empty, facilities for the frail elderly are in great demand, with someone in North America turning age 65 every seven seconds.

Health care delivery will need to be integrated across the continuum of care, from primary care, diagnostics and specialists, through hospitals and community care, to nursing homes, hospice and palliative care. Institutional barriers, professional siloes and the unintended barriers to care created by our health privacy rules will be eroded by technology in the hands of both providers and consumers (who will no longer be just patient patients).

In practical terms, these changes will need to be effected on a regional footprint, involve the full continuum of health care delivery, and address the compensation incentives and disincentives that frustrate integration and best practices. The information technology and alternative delivery infrastructure

on the near horizon for health care will empower consumer demands for as-needed availability, relative performance data, clinical guidelines, personal case histories and treatment options.[30]

Similar trends will affect the continuum of education. The impact of trends in health care and education will be detailed later in this report.

Suburbs designed for families need to be re-engineered to deal with changing mobility needs and the advent of new transportation technology.

Mass public entitlement programs, like medicare and CPP, and large government-employees pension funds depend on a demographic pyramid in which multiples of younger workers at the bottom of the pyramid support the benefits paid to older citizens at the demographic top of the pyramid. When the pyramid begins to narrow at the bottom, the medium-term fiscal and social consequences can be dramatic, especially if not addressed in a timely and actuarially sustainable fashion.

With falling fertility rates, the need for more immigrants becomes acute, both to attract talent and skilled workers, and to recruit less-skilled workers to support the health care and lifestyles of an aging population. Along with large-scale immigration, however, comes the domestic social and political reaction to the societal changes that other cultures and other values bring.

In our historically low-interest environment, many have forgotten the miracle of compound interest. A modest elevation in the rate of inflation or the interest rates charged on government and consumer debt, including mortgages, could trigger a number of societal shocks.

4 Economic and workforce trends

In 2014, writer Ryan Avent canvassed academic scholars and other leading thinkers from around the world and in a variety of fields. He interviewed them about global trends and their implications, particularly for the future of work. *The Economist*'s special report addressed a wide range of often

inter-related emerging economic and societal trends, several of which are important for the focus of this report.

Under the heading "How governments can deal with labour imbalance,"[31] for example, the special report extrapolates some intriguing and novel collateral ideas about the relationships between the housing market and the cost and distribution of labour. In another analysis, it links the impact of trades regulation and wage policy on business decisions to use labour-displacement technology or outsourcing.

The special report also raises the encouraging prospect that two high-cost elements of government budgets, like Ontario's, may see relief. It projects that technological innovation will reduce the high cost of individualized health care procedures and therapies, while expanding the availability and lowering the cost of advanced education and training. These developments would have important implications for workers and their families, as well as for employers, governments, hospitals and universities.

Consider our recent experience, where telecommunications and online marketing overtake the in-person retail experience, in areas as diverse as newspapers and magazines, retailing, travel bookings, culture, sports and entertainment. A century ago, every small town had a bustling commercial core, with a theatre or an opera house, and a half-century later, we saw their successors: the strip plaza and the movie theatre, or a nearby drive-in or video rental outlet.

Today, these retail and entertainment functions have largely disappeared from small towns: typically these functions are now commoditized in major urban centres, shopping malls or increasingly, in big-box power centres, with generic retailing, cinema multiplexes and inherently disposable architecture. Major spectator facilities have become mere adjuncts or (often transient) venues for the marketing businesses of professional sport and popular music, or heavily subsidized local venues for one-time events or travelling shows.

In employment, there is an evident loss in the scope for skilled and semi-skilled, blue-collar employment and income levels are not rising for the majority of Ontarians. By contrast, the 20th-century Ontario economy generated well-paying, trade-union jobs for large numbers of Ontarians. Their purchasing power, in turn, sustained demands for Ontario's economic output, including automobiles and housing, and paid the income taxes that financed public services.

While the rate of unemployment is now starting to decline, Ontario's obsolescent jobs are being replaced with large numbers of more poorly paid and less dependable service-sector jobs. This shift in employment profile means lower capacity to pay taxes for things like infrastructure, and correspondingly, more demands for public services that support lower-income citizens, which are programs that benefit the deserving but usually contribute little to improved productivity of the economy and add to government operating deficits.

Technology also makes many service-sector and other lower-skilled jobs vulnerable to labour displacement, with one expert suggesting that 45 per cent of American jobs, and half of retail jobs, are vulnerable to robotic displacement.[32]

Some are suggesting that we may see a resurgence of manufacturing in North America, including Ontario. Attenuated Asian supply chains, geo-political instability and a desire to have some percentage of product suppliers ready-to-hand could influence corporate decisions. We will not see a wholesale return of manufacturing from Asia and Latin America, nor would pre-existing wages and benefits be assumed. However, some growth could help to sustain or rebuild domestic manufacturing for a North American or even global market. It would, of course, be contingent on achieving progressively greater levels of productivity and corresponding reductions in marginal costs.[33]

5 Environmental and energy trends

Disturbing trends are appearing that affect environmental and energy infrastructure. Sanitary sewers and drainage systems once adequate to face the 100-year storm are increasingly incapable of managing periodic extreme weather events. Water quality and availability are emerging as major issues across North America and around the globe. Environmental impacts are motivating the Gates Foundation to offer rewards for re-inventing sewage systems and household toilets.[34]

Energy infrastructure will be under increasing demands from burgeoning electronic communications and electricity-powered transportation, with pinch-points in transmission and increasing demands for higher (millisecond) tolerances in electricity stability. A benign combination of favourable public and tax policy, technological progress and rising electricity costs will also give rise to a wave of localized micro-generation, from inexpensive rooftop solar generators to district heating and cooling systems.[35] Health and climate-change concerns over fossil fuels have closed coal-fired plants in Ontario, reduced vehicle emissions across North America and Europe, forestalled energy-from-waste and gas-fired electricity-generating initiatives in Ontario, and seen a remarkable growth in public acceptance of nuclear energy (although not yet with a concomitant acceptance of the need for nuclear waste disposal).

Over the long haul, temporary fuel-pump price relief resulting from fracking and low-cost petroleum are likely not sustainable, whether economically (return on capital investment in petroleum sources) or from global public concerns over climate change impacts. Carbon-pricing and cap-and-trade regimes, along with consumer and corporate interest in green energy, ultimately will alter industrial practices and profitability.

6 Political and fiscal trends

At the fulcrum of all of these trends lie government and the public purse. How will these megatrends affect those charged with the responsibility for leading change and mitigating its impacts? Leaders in business and labour inevitably need to engage governments in the task of managing the economy in ways that promote prosperity, sustainability, market fairness, a living wage and quality of life. As "The Third Great Wave" notes, in some situations, this will include a decision by public authorities to exercise restraint. In its words, to "get out of the way" or not actively respond to demands for government intervention from an apprehensive public or entrenched stakeholders facing unwelcome change.

In its Oct. 4, 2014 editorial, *The Economist* also emphasizes the need to act in a way that is not a historic peacetime strength of governments: to be nimble and rapid in their evaluation and response to demands for the right infrastructure. Of equal importance, governments need to create the right social and economic policy environment to meet the challenges of the new Millennium, including decisions to plan for and select the right infrastructure by type and priority. [36]

In the same editorial, two other intriguing ideas were raised.

Although wages have not risen as they did in the early phases of the industrial era in both the developed and underdeveloped worlds, billions of individuals now have Internet access to a vast array of resources and benefits. Communications, information and entertainment are very accessible, but the value of which far exceeds the reach of the masses in previous generations. (Probably with Millennials in mind, it adds: "Few workers would want to go back to a world without the Internet, smartphone or Facebook, even for a pay increase.")

The other observation was the role that technology was playing to compensate for labour-displacement technologies and the loss of major industrial and service employers. Online services like Etsy and Uber have

democratized the local and global marketplace, for everyone from vehicle owners to craftspeople. In June 2015, the BBC profiled how impoverished traditional sari-makers in rural India were using basic CAD and web-based global "fulfilment" to earn much higher salaries than ever before.

Overall, *The Economist* summarized the volatile global situation with this pithy set of observations:

> "… the growing wedge between a skilled elite and ordinary worker is worrying. Angry voters whose wages are stagnant will seek scapegoats: witness the rise of xenophobia and protectionism in the rich world. In poor countries dashed expectations and armies of unemployed people are a recipe for extremism and unrest. Governments across the globe therefore have a huge interest in helping remove the obstacles that keep workers from wealth."[37]

With Greece, the Middle East and North Africa in greater turmoil and more than 100,000 refugees and economic migrants washing up on European shores in less than a year, these predictions have become stark realities. By contrast, from the economic doldrums, countries like Spain and Canada have used "Keynesian" investment in infrastructure and housing to re-employ workers, absorb immigrants and revitalize economies bruised by the recent Great Recession. One thing is clear: financial success by those at the top of the economic pyramid may correspond to regional prosperity, but it does not translate into broad-based growth in regional household incomes.[38]

A number of Ontario civil society organizations, including the RCCAO, have shown leadership. They have promoted innovative initiatives, by arguing for road pricing and asset-recycling as ways in which the infrastructure challenge can be met, by beginning with the all-important question of how to finance it. Linking the demand for infrastructure with ways to pay for it is a major political challenge. It can be a tough sell, if proposed in a political environment where the public is skeptical that its taxes, fees and fares are being put to best use. The recent defeat of the Vancouver region's transport sales tax referendum is eloquent testimony to this disconnect.

A combination of impartial, arm's-length, industry-specific regulation and a focus on direct user-pay, user-benefit fiscal policy seems to be the most promising way forward.

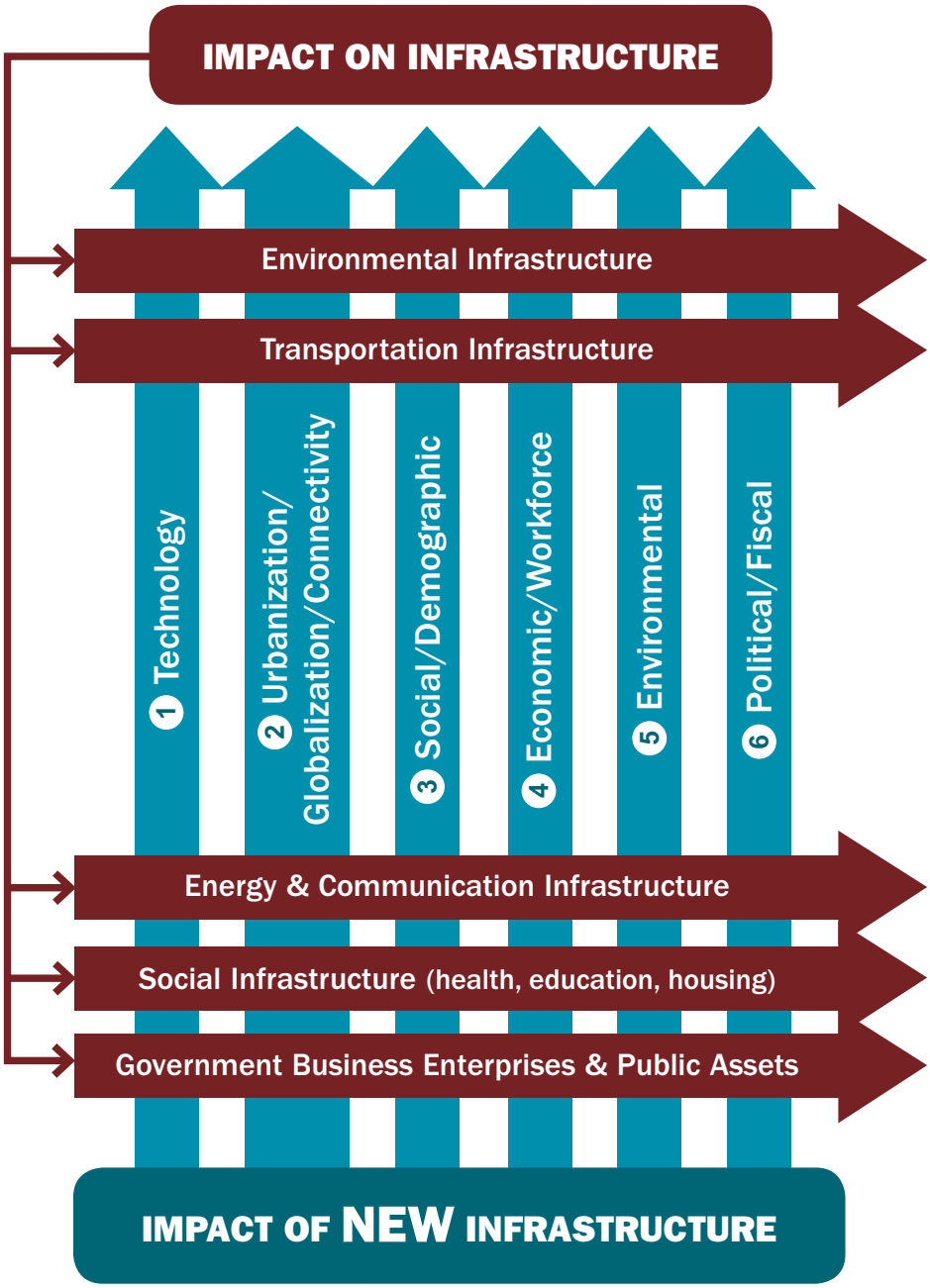
This is not to suggest that financing should be the determining factor in deciding to proceed with a project, or indeed, with an overall government program of infrastructure investment. Simply saying that we have an infrastructure deficit and need to invest, or finding a clever or politically opportune way to attract funding, is insufficient grounds to proceed. Too often, shovel-ready projects and time-limited, politically influenced funding, as well as protracted environmental assessment processes, can coalesce to displace better, future-oriented infrastructure ventures.

In a constrained fiscal environment of capital rationing, with a huge overhang (for now) of inexpensively financed debt, governments have another challenge. They must both build the right infrastructure and build it right, using the most sustainable and forward-looking financial instruments and tax policies.

In our increasingly post-industrial society, we are seeing an evolution of economic production "from stuff to fluff" (to use the evocative term of India's insightful chief economic policy adviser, Dr. Arvind Subramanian). Even in the area of goods production, the "Internet of Things" may diffuse goods production in the same, largely unanticipated way that the mainframe computer came to be rivalled by the personal computer.[39]

Government tax regimes associated with physical assets, fixed-location retailing, local transactions and corporate head offices will need to adjust to new economic models. This is especially true for municipal governments, which build much of our basic public infrastructure, using property taxes, transfer payments and development charges.

Figure 1: The inter-related impacts of trends and infrastructure



Guiding Principles: An approach to planning future infrastructure

Based on our analysis of the research and the comments of those consulted during this report, we have concluded that the direction of technology, economics, lifestyle and public policy share some common characteristics, as we proceed into the future.

These future directions reflect the changing goals of people in society, whether they call themselves citizens, workers, passengers, consumers, patients, students, taxpayers, investors or shareholders. We probed these trends further, for their implications for infrastructure, and a number of intriguing implications offered themselves.

Our approach has not been to try to use a crystal ball. Realistically, we cannot predict the direction of infrastructure with great accuracy, nor can we anticipate all the spin-off effects that might be generated by new infrastructure. But we can provide a telescope and a compass. By reflecting on our findings and their own experience, those in the infrastructure business can better anticipate, prepare and seize opportunities, early and with more confidence. Of equal importance, they can more easily preempt, deflect or mitigate the avoidable risks. There are likely many guiding principles that could be suggested, but we have zeroed in on 11 that will likely determine the future of infrastructure and its effects on Ontario society and its future economy.

1 Distances will shrink

The desire to move goods, people and information quickly, efficiently and economically across a region or across the world will continue – and accelerate. Much of this shrinkage in distances will be abetted by new technology, from the Internet of Things[40] and 3D printing, to high-speed trains and autonomous and driver-assisted vehicles. In addition to the obvious positive aspects, shrinking distances will have a number of disruptive manifestations. It will expand the shadow of urbanization, by allowing long-distance commuting and the development or redevelopment of residential communities and business centres at some distance from major urban centres. It may also risk hallowing out commercial and institutional

bases of second-tier cities and less prosperous parts of the province. These developments will have implications for Ontario's Greater Golden Horseshoe Growth Plan and Metrolinx's Big Move Plan, both of which are based on assumptions that may not prevail in the future.

2 Elapsed times will shrink

From the world of telecommunications and e-business, users of infrastructure will transfer their expectations to public systems, activities and processes. Ontarians will expect infrastructure and the programs it supports to perform instantaneously and simultaneously, not at the pace or in the sequence preferred by the public-agency provider. Demands will grow to deal with cycle-time issues, like reduced waiting times for medical services and more competitive, door-to-door convenience of suburban transit and transportation options. These changes will have dramatic implications for the design, location, operation and, especially, integration – convergence – of infrastructure.

3 Scale will shrink

Moore's Law predicted that miniaturization would exponentially expand the processing capacity of computer chips. The same pattern will be seen in the next generation of infrastructure. Lightweight, environmentally beneficial materials, energy-efficient systems, functions linked with robotics and radio-frequency identification (RFID) communications, and small-footprint engineering and architectural designs made possible by nano-technology, will all be features of the new infrastructure.

While grand infrastructure projects like those of the past will doubtless be needed, modesty and restraint will be important characteristics of urban infrastructure and infrastructure affecting designated natural areas. With a few exceptions, gone is the era of Robert Moses-style monumental engineering works and transportation and utility corridors that cleared all in their path. The constraints that NIMBY and BANANA have imposed on our land-use planning and environmental assessment processes will cause us to rethink the

scale, scope and impact of infrastructure (to say nothing of timing). Tweaking, refurbishing and technical innovations to improve existing capacity will stand equal with the signature project or the innovative new design.

For the foreseeable future, and until the political discourse and fiscal impacts permit it, the localized impact and the anticipated immediate disbenefit will often trump the benefit of modern infrastructure. To win its social licence and political and legal approvals, the new generation of infrastructure will often need to be unobtrusive, make minimal impact, and confer conspicuous and compensating benefits, ideally at a competitive cost.

Perhaps one of the most significant implications of a "small is beautiful" approach is to ensure that existing systems are maintained in good working order and a state of good repair, extending their useful life where possible. Ideally, we should be able to prioritize our investments, to achieve the greatest rate of return. Unfortunately, some of our biggest infrastructure investments lie below the ground, where they are difficult to monitor, hard to maintain and easy to neglect.

Recent government efforts have aimed to improve the asset management practices of all municipalities. Municipalities have been required to inventory their infrastructure assets, for both the municipality's balance sheet and the annual work plan – many of them for the first time. They have also been required to prepare asset management plans, in order to schedule and budget for regular maintenance and rehabilitation. The Association of Municipalities of Ontario has been actively promoting this important work, not only with municipal staff, but also with municipal councillors.[41] More progressive municipalities are using big data to create a fulsome inventory of road, solid waste disposal, water and wastewater assets, targeting system failures, like leakage, waterline breaks and potholes. The result of those latter efforts has been a reduction in the cost of maintenance and repairs, and a much higher level of public satisfaction.[42]

All of this activity gives us reason to hope that infrastructure repair and refurbishment investment can be more targeted. We should aim to ensure a

full lifecycle approach for past public investments and to put off major new infrastructure investments until, and if, they are needed. However, asset management plans also provide sobering evidence of the degree to which we have neglected infrastructure over the years. They illustrate the need to be wise and evidence-informed in making investment choices, with the limited funds available to the public sector for these purposes.

4 Functions will converge

Arising from their experiences with smart-communications, both society and the marketplace will push mergers and interfaces between previously separate and even previously unrelated providers and organizations. This will have significant implications for the providers of infrastructure and for the ability of infrastructure to provide a suite of functions, rather than a single, closely related set of services or individual functions. The public will care less about the provenance of a service than the quality and flexibility of a service. (In the vernacular, they won't care whose name is on the truck or the mobile site, as long as the service reflects good value.) This may have implications for a political system based on division of powers, separation of powers, fiscal segregation and political credit. It also has implications for efforts to restrict data for privacy reasons, and conversely to share data for both governmental and commercial reasons.

An enlightening illustration of the way in which convergence will affect public infrastructure is to look at health care delivery in Ontario, which represents half of the Ontario government's operating budget each year.

As we have seen already in Ontario, there is likely to be resistance to convergence in the health care delivery, unless patients, families and medical practitioners, come to see it as beneficial. For a century and a half, we have developed a health care system that revolves around the family doctor and the hospital – primary care for routine needs, and hospitals for acute care and end-of-life medical and surgical interventions. In the last half-century, we have reinforced this model with the structure of our public health care insurance system (OHIP) and workers' compensation (WSIB).

With greater longevity and advances in health treatments, however, the traditional model needs to change to reflect those it is serving. Life-threatening health episodes are less likely to be associated with childbirth, workplace trauma incidents, or the acute illnesses that ended the relatively shorter lives of our grandparents. Today's end-of-life illnesses are much more likely to be the chronic or prolonged illnesses of the elderly, like terminal cancer, chronic heart disease (CHF), chronic obstructive pulmonary disorder (COPD), hypertension (high blood pressure), renal failure (kidney disease), Type 2 diabetes or Alzheimer's disease. So, while our population will increasingly die from episodes arising from chronic illness, that day can be pushed back well into old age. Chronic health conditions are now commonly maintained by prescription pharmaceuticals and the outpatient services of medical specialists, often in family health clinics.

What does this mean for infrastructure? Hospitals were largely developed to deal with acute episodes, from childbirth to heart attacks, as the formal term acute care facility indicates. (A visit to a hospital ER would illustrate the point, as many with chronic disease episodes or non-urgent medical conditions seek care in that traditional setting). Community-based health care for chronic illness, whether homecare, long-term care, rehabilitation, dialysis, mental illness or hospice care, offer equivalent treatment and efficacy, often with higher satisfaction levels, lower risk of collateral acquired infections and, of course, at a dramatically lower all-in cost to the taxpayer. The same might be said for hospital-based medical testing, diagnostic imaging, dialysis treatments, cardiac rehabilitation and physiotherapy, in relation to privately operated, publicly funded clinics and laboratories.

Does that mean we are building too many multi-million dollar hospitals, at the expense of investments in community-based care and mental health care (and eroding the base for other public charity)? Does it mean that hospitals should increasingly focus on tertiary care, such as complex surgery, trauma incidents and sophisticated cancer treatments? Will the public accept a reduction in the number and convenient location of community hospitals with emergency departments, urgent care facilities and outpatient clinics?

The answer likely lies in ensuring the horizontal integration of health care services and facilities in individual communities – or convergence. It will involve removing the silos and building infrastructure that promotes integration of service delivery along a continuum. It will also need parallel information technology infrastructure, with seamless, confidential transfer of personal health care information as part of that continuum of integration.

In the spirit of technological convergence, a patient's health information will need to be available to the full range of medical practitioners, including pharmacists and nursing staff in long-term care homes. In future, up-to-the-minute health care data will be collected and available from monitoring systems on the patient's wrist or in the patient's home through to various clinical settings, as well as being accessible to the informed patient and/or their trusted caregivers and clinical case-managers.[43]

All of this obviously represents a revolution in the way in which we build health care infrastructure and health information systems, to say nothing of the way we educate, deploy and reimburse our health care professionals and health care workers.

This convergence story could easily be repeated for other areas of the public sector, again with significant implications for traditional physical and technological infrastructure.

5 Margins will decline

As Generation X, Generation Y (aka the Millennials) and new international consumers rapidly become the marketplace, the public's willingness to pay a significant added premium on the price of goods and services as they progress through the value-chain will be resisted – and ways to avoid them sought out by informed consumers and new entrepreneurs. Global competition in other fields has taught these end users and customers that they have options, especially when quality, price or availability of products and services do not meet their expectations.

There will be growing pressure on many traditional protections to value-added services, including our many non-tariff barriers (labour practices, government regulations, market controls, monopolies and concessions, customary business courtesies, etc.). With these pressures on Ontario business will come challenges to their traditional sources of remuneration or profitability, especially if there are emerging, technologically enabled workarounds. Those in the area of suppliers to business – the so-called B2B sector (e.g., subcontractors, material and equipment suppliers, business services suppliers, licensed professionals) – will find their ability to charge for their services squeezed. Their experience will echo the way that, for the past several decades, major North American retailers and vehicle manufacturers have squeezed their domestic, Asian and Latin American suppliers.

In addition to mounting pressure on marginal costs, there will be increasing efforts to link the cost of specific services to specific clienteles. In some respects, government services are society's last frontier in embracing the principles of user pay or beneficiary pay. Beyond charging fees or user charges, in government, there will be efforts to exclude customers or beneficiaries who either do not pay much, if anything, for a public service, who have cost-competitive alternatives or whose economic circumstances do not warrant public subsidy. Finally, as is the case with the rise of electronic banking, retailing and travel planning, the citizen-consumer will increasingly be expected to provide the labour and transaction processing previously offered by providers, through paid staff such as bank tellers, as well as counter staff in offices and retail staff in stores.

6 Individual customization will be expected

We will see a rise in customer-focused individualization. In simple terms, we will see less interest in universal, boilerplate and warehouse approaches, from retailing and logistics, to public transit, education and health care. Processes organized for the administrative convenience or cost-efficiency of public-sector suppliers and providers, from health care to governmental programs, will be forced to reorient themselves to the customer's unique preferences. Fortunately, everything from user-designed smartphone apps to regulatory reforms will make it possible to match consumer needs to infrastructure

options. In many cases, a wider array of individual preferences will be met by bundling common needs through wholesale or trunk infrastructure, while also empowering individualization and citizen choice at the retail or "first/last 400 metres" level. While trunk services, like subway lines, hospitals and wastewater treatment facilities, must rely on a collective model of service-delivery, increasingly the retail side of infrastructure – the "first 400 metres" in transit, or in the treatment of chronic disease – will require new, more flexible, consumer-responsive types of infrastructure and service delivery.

7 Global impacts will become local impacts

The markets for goods and services will reflect changing values and preferences, reflecting the growth of the middle-class in emerging markets. An increase in immigration will also alter domestic consumer preferences, for things ranging from housing choice to education, as they did after the Second World War. Likewise, the ability to source goods, services and information from a global marketplace will devolve to the household level, with implications for things ranging from logistics and order-fulfilment to local production, domestic taxes and regulatory enforcement. With these changes and the connectivity of global commerce, there will be impacts on conventional fiscal arrangements, in much the same way as the private service-sector has had to adjust its business models to survive.

Changing consumer practices and business models will affect: our property and retail sales tax systems and their primary government beneficiaries; zoning and zoning categories; industrial and logistics locations; traffic impacts from changing commercial practices (such FedEx-style in-situ sorting and order fulfilment methodologies, use of drones and declining postal delivery).

Beyond consumer impacts, there are other types of global impacts with unforeseen infrastructure implications. The accidental introduction of invasive species, such as zebra mussels in the Great Lakes, the emerald ash borer[44] and now, beech bark disease[45] in Ontario's timberlands, or the Asian carp in the Mississippi basin (so far), can significantly affect water treatment, shipping and construction practices, and regulatory costs.[46]

With the recent experience of Ebola and Ontario's unhappy experience with SARS and hospital-acquired infections, Ontario's infrastructure – from health care to rapid transit – needs to anticipate a need to control and manage contagions.

8 Climate change will be accepted, but not necessarily its consequences

Extreme weather events will become more commonplace. Ontario may not yet feel the full impact being experienced by other jurisdictions, like drought-stricken California or Australia, or the flooding in Calgary and southern Manitoba. But already, the appearance of so-called 100-year storms, now seen every several years in some parts of Ontario, creates the need for more resilience and redundancy in stormwater infrastructure, bridge designs, water and wastewater treatment facilities, and electrical distribution networks.

Will altruistic policy goals on climate change translate into changing consumer habits or political support for infrastructure-related initiatives? It will depend on their relevance, their political marketing and the tolerance of the average citizen. Ontario's move away from coal-fired electricity generation is now recognized as a positive move. Without more practical alternatives, a similar shift in public attitudes in climate change areas like automobile use, localized energy generation and subdivision design will remain problematic.

9 Demographics will change society's priorities

As the Ontario population moves through the Baby Boom demographic, the political and market influence of the post-war generation will wane, despite its expanding social and health care needs. We will see less emphasis on bricks-and-mortar infrastructure; more electronic communication, in-situ processing and 3D printers. Within the Baby Boom generation, we may see more demand for services and results, and correspondingly less focus on some durable goods (smaller homes, fully integrated Internet of Things [IoT] technology[47], live theatre vs. ATVs, etc.).

This change of emphasis may have some positive aspects. Local theatre, the 100-kilometre diet and home renovations have less economic leakage than buying the latest South Korean entertainment technology or importing Chilean vegetables. The 3D printer and the home office connected to the IoT make for less commuting (although arguably, less need for conventional retailing and manufacturing, and more local delivery traffic from fulfilment orders).

The continuing decline in marriage rates may produce more low-income, single-parent families, and a corresponding upswing in the need for certain public services.

10 New consumer-driven urban designs

Some have predicted that an increase in interest rates will force a correction in the cost of housing and the level of household mortgage debt. However, the U.S. experience after the sub-prime debacle seems to suggest that any declines are short-lived and mortgage indebtedness tends to create resistance to accepting downward price corrections by much of the marketplace. As the cost of home ownership continues to rise for post-Boomer generations, especially the price of so-called land-related housing (semis, single-family, townhouses), new models of urban residential accommodation will emerge.

The likely prospect is that Ontario will move beyond simple intensification and natural areas policies, which are already generating both community resistance and, ironically, a re-emergence of metropolitan-scale urban sprawl. Our cities and towns will need to redesign themselves and to build new models.

The needs are becoming obvious:

- More robust stormwater management;
- Elderly-friendly transport;
- Safety and health as criteria for public transportation infrastructure and housing design priorities (personal mobility, health promotion, perceptions of personal safety, school busing and child safety, epidemics and crime);

- Reduction in overhead wiring to accommodate greater use of drones and improved aesthetics, even as rail corridors electrify;
- New types of homes and other living accommodation and new communities, with extensive domestic use of RFID technologies and supported by cheap, longer-distance rail communication, not yet seen in North America;
- A return of the importance of ports as logistics hubs, and greater short-haul water transportation in the Great Lakes Basin; and,
- The re-engineering of our suburbs to reflect less dependence on the car and easier, less expensive maintenance of public and private amenities, and housing with fewer stairs.

11 The perils of 'short-termism' must be overcome

Political, media and investment horizons have diminished, with the 24-hour news cycle and business performance based on the latest quarter and the closing stock price. These are more often seen as concerns for corporate boards of directors and political candidates.

However, this same "social-media attention span" will make it increasingly difficult to anticipate, manage and motivate decisions focused on medium-term and longer-term trends (aging population, climate-change and extreme weather effects, long amortization infrastructure investment, prioritization of significant (vs. insignificant) environmental trends and impacts, shifts in regional prosperity and growth, etc.). Politicians at all levels are driven to think in four-year electoral cycles and increasingly, they are in permanent campaign mode, requiring political donations to sustain the march.

A related issue is the relationship between organizations and those they serve. In the United States, the courts have told the boards and CEOs of distressed companies or companies targeted for mergers and acquisitions that their sole responsibility is to their shareholders. The Canadian Supreme Court has been slightly more Canadian in its outlook, adding responsibilities

to a wider array of stakeholders (workers, pensioners, suppliers, creditors, customers and the communities within which the companies operate).

The bottom line, however, is similar throughout the developed world. For business, long-term considerations are increasingly subservient to the here-and-now: share price, return on investment, dividends paid, analysts' projections, last quarter earnings and the demands of the hedge funds and activist investors. This economic and legal environment makes it difficult for either business or labour to consider future opportunities, invest confidence in the future of companies or preserve economic potential for future generations. In this atmosphere, governments at all levels must play their historic role: setting the rules of the game, promoting productivity and broad-based prosperity, and considering the future as well as the near term.

Are governments up to these tasks?

In a world of "**short-termism**," can governments discharge this future-oriented role? How might this be done? What changes in our structures, processes and mandates are likely to empower governments to play this forward-looking role? With whom should governments work to ensure that future infrastructure investments sustain our future?

The societal changes and infrastructure challenges that we have highlighted in this report share a common feature: they need to be anticipated by decision-makers – accurately and well in advance. But our 24-hour news cycle, the expectations of market analysts and the rise of social media, increasingly drive our political, business, labour and civil society leaders to the short-term time horizon and the here-and-now. Short-termism is not only a threat to business performance and environmental sustainability: it makes effective infrastructure planning very difficult and prone to greater risk of waste and system failures.

Other jurisdictions have addressed this problem with imagination and success. The rigour and evidence-based approaches to collaborative infrastructure planning and implementation in jurisdictions like New South

Wales, Singapore and even the U.S. Environmental Protection Agency are a model. They appear to have made real progress in overcoming short-term thinking and unsustainable practices.[48]

New infrastructure and its effects on society

- How will future trends change infrastructure's capacity and form?
- How will society's needs for infrastructure change?

We have concluded that megatrends yield 11 Guiding Principles that will affect both infrastructure and its relationship to society and the economy. In combination, these Guiding Principles will have a bearing on the way in which we organize ourselves, both to go to work and at work, as well as the lifestyle and urban environment that we will enjoy when we are not working.

What are likely to be the most significant new developments? Which can be managed, changed or mitigated? Which must simply be anticipated and accommodated? Ideally, seeing accurately (or at least with flexibility) into the future should give us all a head start on new developments and wise investments. If so, that they can favour us, our economy and Ontario society, into the future.

If we look at the 11 Guiding Principles that we have identified, what can we expect in practice?

New types of infrastructure

One of this report's conclusions is that the next generation of infrastructure may benefit from new technology by altering the nature, weight and footprint of traditional infrastructure.

For example, we generally assume that our existing water and wastewater network is universal and standard. In many parts of the U.S., parallel gray-water systems are commonplace; piping lightly treated or recycled water for use in landscaping, industrial and construction uses and other non-potable applications. A newer design of domestic toilet technology, completely

different than that in use in Western countries, was adopted in post-war Japan. The work of the Gates Foundation, while targeted at innovation in Third World sanitation systems, could easily produce a next generation of domestic sanitary sewage systems that would revolutionize our vast and capital-intensive wastewater infrastructure.

Heavy infrastructure, like electricity generation and distribution, heavy-rail transit and trolleys, urban street standards, hospitals and college buildings could be increasingly paralleled or even displaced by lighter, more flexible, lower-cost options. If so, the pace of infrastructure investment may accelerate and resistance to it decline. The challenge may lie in distinguishing the next generation of new infrastructure from the fads.

Long-distance commuting

Next, it seems logical that the next generation of infrastructure users will expect to be able to move considerable distances regionally, rapidly, conveniently, frequently, safely and at low cost. Rising housing prices in major centres will be a factor as well. These people may want to live in one city and work in another, as their spouse/partner travels from home in the opposite direction for his or her work or study. As many more Ontarians will be self-employed and seeking work where they can find it, they will want to be able to serve a much wider market area. These are commuting patterns that are not anticipated in our traditional hub-and-spoke transit and transportation models, in which we have continued to invest so heavily. These new commuting patterns are an example of the individual customization that will be expected.

Light and flexible infrastructure

Infrastructure that will accommodate this kind of highly mobile society will need to be inexpensive to build, maintain and operate. It may also have a much shorter lifecycle and amortization period than traditional structures and methodologies. In some cases, infrastructure may need to be moved or reformatted before the end of its planned life. In particular, new transportation infrastructure will need the flexibility to alter its delivery

model and scale, when volumes or directions change due to economic conditions, new urban growth patterns or changing demographics. Transit will look to the experience of the Docklands Light Rail and York Region's Bus Rapid Transit (BRT) network for practical, lower-cost and more flexible responses to evolving and changing commuter needs.

On the local level, the design of neighbourhoods and communities will undergo a similar reconsideration. The rationales will range from better health through promoting physical activity (among the young, the old and the sedentary), to a desire to reduce the frequency, severity and cost of injuries caused by automobile accidents, through to a goal of reducing the cost and upkeep of civic infrastructure and the operating cost of municipal services.

Think globally, act locally

We can anticipate innovations from elsewhere being adopted here, with these current innovations as a sample:

- The widespread use of heated sidewalks and intersections (Montréal);
- The reconfiguration and sequencing of traffic signals to promote intersection clearance by turning vehicles and safer right-angle road-crossing by pedestrians and cyclists (Madrid);
- The elimination of raised curbs on streets where the street-function can change with time and season (Montréal);
- The creation of zero-injury design modifications and programs (Stockholm), such as roundabouts (whether new, like Milton, Ont., or reengineered, as in Naples, Fla.);
- The great increases in urban cycling (in part due to reduced cyclists' and motorists' anxiety over "dooring" and right-of-way conflicts) that come from two-directional, physically segregated bicycle pathways on urban roadways and between suburban subdivisions and transit hubs (Madrid, Copenhagen, Amsterdam, Montréal);

- Public transit models and other public transport options (taxis, jitneys, informal transit, etc.) that address the "first 400 metres barrier" to broad use of public transit, and to focus public expenditures on efficient rapid transit and inter-urban transit rather than costly, feeder systems (Santiago, Chile, and Hong Kong).

'Convergence' of infrastructure

Many traditional public and community functions will converge, with the result that traditional segregations will make less sense. Customary distinctions, like those between school systems by physical plant and busing, or the segregation of police, courts, incarceration and release-monitoring facilities for reasons of juridical appearances, may erode. Most conspicuously vulnerable to convergence are the distinctions based on geography, municipal ownership, trade-union jurisdiction and so on.

With the convergence of miniaturization, pre-constructed components, and new building materials, the infrastructure of tomorrow will include more **light infrastructure.** It will have a shorter life expectancy, new materials and designs, more capacity to be adjusted to meet changing use-patterns, demographics or economics, and with a lower impact and price tag. (Again, the Docklands Light Rail or York Region's Bus Rapid Transit.)

Paralleling light infrastructure is the retrofitting and repurposing of existing infrastructure, to increase its resilience, its through-put, or its life expectancy, as an alternative to the daunting task of securing approval for major new heavy infrastructure projects, networks and utility corridors.

The use of bank-affiliated, smartphone-based fare-media will drive convergence in a range of transportation options. These will include: integrated distance-based fare regimes for local and regional transit, on-street and off-street parking location and fee-paying; new formats for taxis and taxi alternatives, including ride- or vehicle-sharing services like Uber, Car2Go, AutoShare and ZipCar; and, RFID-triggering of intelligent transportation networks and GPS guidance, and other in-transit applications, including

coffee purchases. Another manifestation will be the wider use of Ontario-pioneered transponders for automobile pay-by-distance road-use, HOT lanes, automobile insurance applications, and aggregated traffic management data for use by civic authorities.

A new look for health care integration and infrastructure

As noted earlier, the cost of public health care consumes nearly half the annual operating budget of the Ontario government and is arguably a major contributor to Ontario's deficit and debt levels over time. With the impact of demographic trends and new medical technology, these costs will continue to rise. Evidence-based best practice, from organizations such as the McMaster Health Forum, tells us that we can achieve better health results and lower costs, if we can ensure that the right care is offered at the right time, in the best venue. Chronic disease rather than acute incidents consume ever more of our health care dollar. In the 21st century, most of us will decline and die from complications of chronic disease, rather from an acute incident or contagious disease, as would have been the case in the last century.

Unfortunately, most of our health care system, and the infrastructure that sustains it, reflect past practice and the sector silos within health care. Primary, specialist and surgical care is still largely organized (and paid) to address acute incidents and manifestations of chronic illness, rather than health promotion and case-managing chronic disease. Similarly, hospitals are highly specialized, expensive venues that are better suited to deal with acute illness and injury than the lingering and recurring incidents associated with chronic disease, especially among the elderly and frail. Indeed, frequent and longer hospital visits can add to the problem, through the prevalent risks of hospital-acquired infections and sedentary treatment practices. Finally, long-term care (nursing homes) represents a significant public investment in end-of-life care that will likely be overwhelmed by the numbers as the Baby Boomers age.

Best practice tells us that avoiding ER visits, hospital admissions, long-term stays, frequent re-admissions and delaying premature admission to nursing homes, will achieve better health results for those living with chronic

illnesses, as well as reflecting patients' preferences. Serving a growing and aging clientele in their homes and in community settings is also far less expensive and more time-responsive than the costly institutional alternatives. Good medicine is also good fiscal policy.

Yet we continue to expand hospitals and their treatment mandates, and try to stay ahead of the demand for government-subsidized nursing care beds in private and municipal long-term care homes. While Infrastructure Ontario's procurement program has imposed long-overdue constraints on the cost of hospital construction, public and philanthropic funding for hospitals continues to reflect obsolete assumptions. The Ontario government funds most of the capital cost of "bricks and mortar" but leaves much of the increasingly expensive in-house technology to be funded by other means.

From a nominal "good faith" contribution, municipal capital contributions to hospital expansion programs have grown to be sizable "enforced charitable donations" levied on residents and business, and drawn from an overburdened tax base never intended for such commitments. More fundamentally, it is proving difficult to persuade government (and health care providers) to move funding from the institutional "envelopes" to fund the infrastructure and operating costs of community-based health service delivery.

Health care is a primary target for "convergence" of infrastructure. Ontario needs to meet the evidence-based test of "right treatment, by the right provider, in the right place, at the right time, for the lowest cost to the taxpayer." Integration of health care delivery, as envisaged by the Local Health Integration Network legislation, is the key to making these evidence-supported choices. Underlying these choices is ensuring that our infrastructure investments and funding policies anticipate, facilitate and support those right choices.

The same convergence principle applies to integration and seamless transfer of patient information through contemporary technological infrastructure. Health care's institutional and professional silos, and privacy legislation

constraints, restrict effective and timely transfer of important medical and pharmaceutical data from provider to provider, and to the patient and family caregiver. Despite our investments and progress in areas like diagnostic imaging and laboratory testing, we still do not have easily transferrable electronic medical records and electronic health records. Personal health data is neither intelligible nor conveniently available to the patient and family caregiver. In Ontario, we all have more electronic information about our cars and our cats than we do about our health.

In the health care field for the foreseeable future, hospitals, urgent care centres, hospices and palliative care homes, and technology-enabled, elder-friendly residences will need to be designed so that both structures and incentive systems promote integration. But compensation remains a driving factor in human behaviour as much in health care as any other sector:

- As long as in-person visits and approved OHIP codes are the only way some health care professionals are paid, telecommunications and home-based therapies will not be effectively employed, and waiting rooms, ER backups and fax machines will remain features of our health care system.

- As long as similar kinds of professional services and personal services are compensated differently among hospitals, private clinics and laboratories, community care access programs and long-term care homes, integration will be difficult and sub-optimal, and potentially risks driving up health care costs for all of us. The resolution of this dilemma will determine the nature, scale and location of health care infrastructure, as well as the investment required.

- As long as hospitals are the venue for high-volume, specialized medical practices and the best way to pay for those professional services, other viable options are unlikely to grow. If, however, the compensation regime in health care, in all its many manifestations, can be matched to evidence-based clinical best practices and value-for-money delivery models, the nature of publicly funded health care infrastructure might change quite dramatically.

A new look for public education and its campuses

In the field of post-secondary education, the big campus will become less significant for two reasons.

- As an educational venue, universities and colleges will be challenged by the availability of readily accessible, recognized programs featuring the world's best researchers and instructors, in inexpensive and student-determined delivery models.[49] At the same time, we will see an expansion of Ontario-based services – some offshore or U.S.-based – offering university-style learning in a convenient commercial setting, or even in decommissioned public buildings, like closed public schools.

- As a preferred venue for self-directed primary and applied research conducted under the tutelage of tenured professors, the university will also be challenged by the range of alternative research venues, some of them spawned by the university itself. In fields farther removed from bio-medical, technological and commercial research, the ability of universities and colleges to justify their substantial, continuing commitment to research as an adjunct to instruction or in place of teaching, will be harder to sell to cash-starved governments and competitive philanthropy.[50]

At primary and secondary school levels, the shrinking, shifting population of school-age children will put pressure on school boards and governments to repurpose and dispose of valuable land assets occupied by underutilized educational facilities. This may be accentuated by trends that diminish the primacy of public education, in favour of alternative schools, emphasizing religious denomination, program variety or quality of educational achievement.

- The retention and refurbishment of public educational facilities implies a continuing societal commitment to the existing model of public education – arguably a matter of disagreement and comes at considerable taxpayer expense. Such a reinvestment will likely need to be preceded by a societal re-commitment to restore public education as a fundamental vehicle for social integration in an increasingly diverse population.

- In other provinces, a review of public education and its funding has extended to a reconsideration of equating of linguistic and religious education obligations with the need for separate facilities or separate school administrations. In other words, the future may see combining schools and school boards, for reasons of operational and infrastructure efficiency. For a variety of pedagogical and sociological reasons, it might also result in a reconsideration of the size and scale of school facilities and the volume of school busing, at both the primary and secondary level, resulting in more small schools and the decommissioning of mega-schools.

- Above all, such a recommitment to public education would also, realistically, need to address issues of quality, stability and value for money that appear to be undermining public education's traditional, broad-based public support.

Demographics and their implications

As the demographic challenges facing the labour market intensify (and the need for young taxpayers and pension contributors grows to support the cost of services to the Baby Boom generation), our population will see increasing diversity. The next wave of immigration will be based not so much on our international treaty obligations for refugee resettlement or our traditional openness to economic migrants. In the future, immigration will reflect our need for the skills and innovative drive of offshore talent and, realistically, the personal care-giving needs of an expanding frail and elderly population. Given the global migration pressures of war and poverty, we may also be increasingly affected by the pattern of "informal" immigration seen in Europe and the U.S.

The prospect of the public building long-term care homes, palliative care wards in hospitals and similar infrastructure for a whole generation appears unsustainable under the present fiscal circumstances. Technological and medical measures to maintain the elderly in their homes and in commercial residences for the elderly will expand dramatically.

Linking infrastructure and work – in society, in productivity, and in building and maintaining infrastructure

How will the future of employment and the future of infrastructure interact?

We have identified the trends and factors that will determine or at least influence the infrastructure of the future. What will that new infrastructure mean for those who work in the Ontario economy or whose lifestyle is supported by it? In addition, it would be useful to explore the roles to be played by those who presently design, build, finance, operate and maintain today's infrastructure, and the roles for those who come after them.

As distances shrink, turnaround times are reduced, miniaturization continues and functions converge, infrastructure will change. It is equally intriguing to speculate on the degree to which those same factors will alter the work of those who work in and with infrastructure.

Workers may find that they can (or must) live at considerable distances from their workplace. Availability for work may involve shorter notice and shorter duration – and it may draw from a much wider labour market in terms of both geography and skill requirements. As the nature of infrastructure incorporates more sophisticated materials and technologies, the need for continuous training and education will also increase, including the need for newer forms of safety and materials handling training.

The recognized productivity of the Ontario construction trades is based on a model that produces performance excellence from good initial training, followed by improvement through additional training, practice and repetition. Parts of the construction industry, by the nature of the work involved, has been somewhat insulated from labour-displacement technologies, such as we have seen in other industrial sectors, like manufacturing or primary industry. But the rapid evolution of robotic technology will have the kind of impact on construction that it has already had on manufacturing.

How will labour be affected by the new infrastructure?

On the positive side, a great deal of activity in the infrastructure field means more work for all in the construction trades and in the professions that support it. However, the enhanced technological component will require more training and skill specialization. It will also reduce the demand (and labour-market wage rates) for unskilled and semi-skilled workers. Those who once manually graded roads and spread tar, with the proper training became heavy equipment operators. In much the same way that the job of the automobile mechanic has morphed from engine repair to computer diagnostician, the new infrastructure's impact on skilled workers will not so much displace old skills as require them to be supplemented and reframed.

The demands for reduced marginal costs will put pressure on those engaged in building and operating infrastructure, which will reflect itself in collective bargaining and in increased use of pre-assembled or shrink-wrap approaches to installing and maintaining infrastructure. Plug-and-play, rather than build or repair, may be the preferred format for building

and maintaining infrastructure, much as it has become in appliance repair, HVAC maintenance and automobile repair. In a global labour marketplace, the competition for talent will go beyond our experience with importing foreign workers for construction jobs, to a full-fledged competition for talent at all levels of skill and experience. Pressure will be felt to reform traditional controls on new entrants to the workforce and to reevaluate the criteria for recognizing international qualifications and professional certifications.

Again, on the positive side, the growing interest in creating a Great Lakes marketplace for infrastructure projects will favour Ontario's companies and workers. To do so, we must anticipate the needs of the next generation of infrastructure and remove our self-imposed restrictions on the awarding of contracts and the movement of labour. In fact, as the appetite for building major infrastructure continues to grow in the developing world, we may see something of a reverse flow, with Ontario workers taking jobs that involve transferring skills to local workers on overseas projects.

Convergence is a trend that will confront the workplace. As the traditional distinctions between types of work blur, distinctions in job descriptions and classifications become less meaningful.

There will be an impact on work from the inevitable shift in the kind of projects being undertaken, both large and small. In areas where major public institutions, big residential developments or large-scale engineering works will be less common, the focus may shift to refurbishment, decommissioning and repurposing. A multiplicity of small-scale projects may fill the order books of firms that used to hire for long-term, single-site projects. In some cases, skills learned in one sector may need to be modified and applied to jobs in a new, related field of infrastructure.

Finally, with the retirement of our current workforce, we will need to find practical ways to introduce a new generation to infrastructure work. We will need to do it in a fashion that meets the next generation's different perspectives of work, while maintaining efficiency and production. It must

also be done in a way that balances the need to preserve good wages in an environment of pressure on marginal costs. If our costs are too high, or our productivity cannot match that of others, our ability to afford infrastructure will be jeopardized, or external forces may offer non-traditional solutions to achieve the results that Ontario society and business demands.

Infrastructure that we may see (or not) – but may need – in the next generation

In examining and responding to impending trends within infrastructure and the trends affecting infrastructure, the role of government has always been central. From ancient times, it has fallen to civic authorities to design, build and operate crucial civil infrastructure. This mantle has included the obligation to anticipate social and economic needs but also, to use infrastructure to create new possibilities. From Roman aqueducts to fibre-optic broadband networks, successful infrastructure often requires new ideas and new approaches to anticipate needs and to serve public policy and economic objectives. When done well, major infrastructure development can change a society for the better and assure its continued prosperity, as with the original building of Hwy. 401 or rural electrification of Ontario.

For this reason, it is important for government to have a capacity to look beyond precedent, past practice and near-term horizons in dealing with the needs of the future. As is so often the case with societal innovation and social progress, however, the institutions responsible for meeting emerging societal needs (governments, major corporations and civil society organizations, like universities or the media) – may not always be in the best position to propose reform or to advance radically new ideas. Despite rapid advances in technology and engineering potential, both governments and their private sector and civil society counterparts, are often reluctant or unable to break free of the constraints of convention, risk-aversion, complacency and cost.

A Transportation infrastructure

- In the future, transportation infrastructure may be supplemented by the need to support high-speed interurban passenger rail services, if the level of ridership and population can sustain it. As well, rail has become a major means of transporting commodities, such as heavy oil and dangerous chemicals, needed by society and the economy, but whose transport brings risks, especially in densely populated areas.

- Transportation infrastructure will increasingly include intelligent transportation systems (automated vehicle control, road pricing, expressway system-access controls, etc.) and computer-aided logistics and dispatch, from supply chains to new formats for ride- or vehicle-sharing or load-sharing commercial transport. The same pattern will visit itself on rapid transit, with platform-side doors, automated train control and time-of-day and distance-sensitive fare-media. Grush's and Niles' observations in Appendix C about the impact of automated vehicles and sharing on public transit and personal-use vehicles are especially relevant here.

- Technology will target the mounting problem of deferred maintenance obligations in public infrastructure, which now also burden the financial balance sheets of municipalities and public agencies. Nano-sensors built into roadways, bridges, parking garages and under-road water and sewer networks, along with the expanded use of monitoring/inspection technology, will enable a more targeted "no-surprises" approach to maintaining existing infrastructure. When evidence-based findings displace depreciation-based programs of comprehensive maintenance, money and resources can be more effectively prioritized and extend the useful life of physical assets. Technology can also enable a comprehensive, evidence-supported approach to asset management, as in cities like Cambridge, Ont., and Ottawa.

- In future, aeronautical infrastructure will be supplemented to manage drones and other unmanned craft, for use in consumer and commercial applications. As well, the steady compounding of global air traffic will necessitate investment in new, more flexible air traffic control systems.

- Freshwater transport throughout the Great Lakes has a bright future in inexpensive, environmentally beneficial international and domestic shipping of bulk commodities, agricultural produce and other goods. However, it also faces challenges: the impact of new Panamax and larger salt-water vessels unable to use size-limited freshwater ports, locks and canals; regulatory and taxation impediments to waterborne trade, especially on the U.S. side of the border; the expense of maintaining well-dredged harbours and channels; and the need for better integrated multi-modal transport hubs and incentives to use them.

- In common with other transportation and energy infrastructure, ports face competition for well-positioned real estate. There is risk of losing port lands and utility corridors to competing land use demands, such as residential development and recreational uses, which often represent short-term political or financial gains, but with long-term negative consequences for good infrastructure.

- Continuing urbanization in Ontario and the growth of its major urban centres will require much broader and more integrated regional transit and transportation planning than has been the case in the past.[51]

- As part of technology-driven "fare-media" integration, customer choice and service convergence will be major determinants. No longer will transit infrastructure be built primarily because that's where the rights-of-way already exist, or based on current or past commuting patterns. In particular, transit service infrastructure decisions will not be made primarily with a close eye to municipal boundaries, restrictions in collective agreements, protecting fare revenues, or local or regional system ownership (including public vs. private).

- Integrated fare-media using smartphones and RFID credit cards will allow passengers to decide where they will park, which transit infrastructure or alternatives they will use, other in-transit applications, including coffee purchases and ultimately, where they will travel. Armed with the financial

power of integrated fares and smartphone applications, passengers – not providers or politicians – will increasingly determine the transit route map, service levels for mass transit and the popularity of fare options. Simply building infrastructure because we own the right-of-way or need to respond to time-limited pressures can lock in patterns and infrastructure investments that are sub-optimal. The criteria should increasingly be "customer-based": elapsed time, fluctuating work locations, number of vehicle changes, changing consumer preferences and price of convenience.

- In this environment, flexibility will be important, favouring adjustable, shorter duration, less expensive transit infrastructure. Examples might include: bus rapid transit vs. light rail; awarding proof of concept or low-performing intra-regional bus or light-rail route concessions to public or private providers; encouraging informal services to feed rapid transit routes; and, using or creating Madrid-style regional terminals with inexpensive parking and good connections, to siphon off peak flows from routes like Yonge subway or to mitigate capacity constraints at Union Station.

- To reduce public education cost pressures, as well as to enhance the viability of municipal transit (especially for poorly performing routes or infrequent services), governments may decide to redeploy "yellow bus" subsidies – by providing incentives for secondary school and college students to shift to municipal transit and away from expensive, no charge school-bus and college shuttle programs.

B Energy and telecommunications infrastructure

- In the future, energy infrastructure will need to be extended, in order to improve the electricity grid, to overcome transmission capacity bottlenecks and to exploit generation business opportunities. On a macro scale, this might include linking Bruce Power's surplus nuclear power supply and storage capacity with U.S. markets, as well as improving linkages between Ontario markets and electricity supply from Hydro Québec.

- On a more localized basis, it will also include overcoming regional bottlenecks, such as transmission to the Toronto and region market from generators east of the city and linking northwestern Ontario supply with markets east of Lake Superior.

- If the damaging impacts of coal-fired electricity generation come to be accepted by mid-western and northeastern U.S. States, business opportunities will increase for major Canadian surplus clean energy electricity generators, like Bruce Power, OPG and Hydro Québec.

- Telecommunications infrastructure will likely be supplemented by expanded use of closed-circuit television systems, and security infrastructure related to monitoring and interception of telecommunications and RFID electronic signals for a wide variety of personal, household, business and public security uses. Mobile communications are exploding, as is the demand for Internet access at higher and higher speeds.

- Telecommunications infrastructure based on distributed cable networks and fibre-optics depends on a reliable consumer base. The growing pattern of households in English-speaking Canada abandoning both cable television and residential land-line telephones has major business implications for builders of telecommunications infrastructure.

- Much of the infrastructure for this is created by private sector suppliers (Bell, Rogers, Telus, Xplornet in rural areas, etc.), but given the importance of such infrastructure for our economic future, governments and consumers may well ask: "Are we being adequately served by regulated oligopolies? In places like Singapore and South Korea, the value of public investment in telecommunication and electronic infrastructure is evident. Are we being left behind?"

- In the future, the patterns of electric power use and production will change, requiring alterations in the infrastructure for power production and distribution.

- The emergence of widespread and increasingly competitive rooftop solar power panels, coupled with local electric power storage systems, such as the Tesla Powerwall, are going to radically and unfavourably change the economics of electric power utilities.
- Some suggest that next-generation solar generation may radically alter the economic value of conventional power generating capacity. Only the lowest cost generators may survive. The risks are real, especially given the scale of investment required.

If these possibilities come to pass, such changes would require a major rethinking of Ontario's power infrastructure. It may be that the power transmission grid will become more valuable than Ontario's power-generating capacity.

- Energy infrastructure will need to be extended in places, in order to improve the electricity grid, to overcome transmission capacity bottlenecks and to exploit business opportunities for power generation. It will also give rise to a wave of localized micro-generation, from increasingly inexpensive rooftop solar generators to district heating and cooling systems.

C Environmental infrastructure

- Ontario communities have long resisted expansion of landfill sites for solid waste disposal and, in particular, energy from waste-incineration plants. Ambitious programs to promote waste recycling and resource recovery have helped to mitigate the impact of this reluctance to accommodate regional waste disposal, but costs are high and markets for most of these products are soft, especially with the decline of the newsprint industry.
- In the future, when commodity prices for aluminum, steel and precious metals justify it, existing and closed landfill sites may afford opportunities for recovery of metals, as well as established technologies for recovery of methane gases for energy generation. Energy from waste facilities are increasingly using advanced technologies to mitigate real and perceived environmental and health problems with these facilities.

- In the future, extreme weather events and other climate-change provisions may expand the scope of infrastructure related to mitigation and rapid recovery from wind, rain and ice storms, flooding and sewer backups (both sewage and stormwater). We will also see proposals and mounting pressure to transport some of Canada's abundant (and often shared) freshwater resources to the drought-parched areas of the U.S., including drawing down water on shared waterways, like the Great Lakes, the Red River basin and the Columbia River system or freshwater swapping with the Hudson Bay lowlands watershed.

- Climate change threatens to alter precipitation patterns and may reduce the ready availability of fresh water supplies in various locations around Ontario. Other factors also impinge: society's tendency for chronic under-investment in supply due to the out-of-sight, out-of-mind nature of potable water systems and the abuse of low-cost, conveniently available water supplies. Despite our superficially favoured position on the freshwater Great Lakes, we could see water shortages, similar to those already afflicting the western United States and Australia.

- Shifting weather patterns may also require changing building standards and construction materials. A warming climate could bring to Ontario the so-called Tornado Alley of the U.S. Mid-West. Current building standards do not contemplate regular, violent storms and flash floods. But our next-generation infrastructure may need to anticipate it. In some jurisdictions, anticipating new risks, like better seismic or stormwater protections, has increased the previously projected replacement cost of existing infrastructure.

- In the future, building techniques and building materials will be asked to address a range of needs, beyond current LEED standards of sustainable accommodation and energy conservation. Building shells and paved surfaces that respond to environmental considerations, like smog or rainwater preservation, will become more common and may be required by building codes.

- There will be pressure (and opportunities) to find new building techniques and to find new applications for existing models of infrastructure and, perhaps more importantly, to try new materials and designs. This will demand new flexibility in government tendering and requests for proposals, focusing on performance-based specifications, and new ways to test the adequacy and compliance of new products, techniques and designs. In our present environment, where concerns over liability, cost-containment and political embarrassment produce much of the volume of public procurement documents, the future will call for new approaches by both government and the construction industry.

- Incorporating innovative environmental and energy features into construction projects will not be smooth sailing. We know this from our experience with things like retrofitting green roofs, incorporating stormwater features into surface parking, energy-efficient concrete construction and, recently, securing approval for mid-rise timber-frame construction. The biggest challenges will be to introduce reasonable compliance, testing and liability contract provisions for things that go beyond the scope of traditional construction specifications, like air-quality enhancing building shells or cost-efficient, aesthetically acceptable energy supply for infrastructure projects. If government is to realize the great opportunities created by unleashing the creativity of the construction sector, including architects, engineers and builders, governments must provide realistic incentives and assurances, not just invitations to be innovative.

D Social and health infrastructure, and policy

- Another trend is the ubiquitous use of electronic and wireless monitoring equipment. For health care, care for the elderly, and even custodial care of low-risk offenders, these may be outsourced from expensive, employment-intensive physical plants (hospitals, long-term care homes, prisons) to community-based or home-based settings. At the same time, there will be a dramatic increase in demand for personal care workers of various kinds to cope with the health and acuity issues of the Baby Boomers, and to take the low-skill and higher skill jobs that natural regeneration and other factors leave unfilled.

- Likewise throughout the educational system (as we are already seeing at the post-secondary level and in skills training), considerations of quality, delivery cost, individual pace, child-safety and convenience may accelerate an emerging shift in teaching and learning towards telecommunications-enabled settings. Increasingly, as TED Talks and MOOCs (Massively Online Open Courses) demonstrate, the world's best professors and researchers can be accessed at times and in the preferred settings as chosen by students, at a fraction of current costs and with a global scope and the potential for global interaction. The world of paper textbooks, crowded lecture halls and insular local institutions is already looking obsolescent or even obsolete.

- The high cost of post-secondary education and its time-honoured, tenure-based work environment, the pervasive use of low-cost teaching assistants and similar instructional practices, and the predisposition of many universities to favour research over teaching, may lead to the student market voting with its feet, especially as graduates emerge with heavy student debt loads, and often minimal employment prospects. If post-secondary institutions' monopoly hold on credentialling can be legitimately loosened, physical campuses may give way to alternative, even virtual venues for specialized education and research collaboration. Indeed, such virtual campuses are springing up around the globe, and now need to be taken seriously.

- **Schools:** How should we manage the portfolio of Ontario elementary and secondary school buildings in the face of: (a) projected declines in student populations; (b) the continuing shift of populations from rural areas to urban areas; and (c) the rapid growth of the suburban and exurban areas of Ontario's major urban centres, especially in the GTHA?

- **Prisons:** America's 40-year experiment with high levels of incarceration has shown quite clearly that prisons are neither cost-effective nor socially effective. Public policy will increasingly examine the cost benefits of alternatives for effective law enforcement and peace keeping. The answers

will have significant implications for infrastructure intensive public services, like prisons, courts and police services, as they are put through an unfamiliar return-on-investment or pay-for-performance bonds test.

- **Public housing:** Just as prisons are proving not to be cost-effective, homelessness and lack of housing affordability imposes disproportionate demands on the public purse in policing, health care, shelter costs and income support, as well as creating social divisions and dissatisfaction. The costs and potential ROR of investments in public housing, as well as other means of reducing the public burdens of homelessness and poor housing affordability, will drive new, more innovative solutions to housing, including physical infrastructure ideas like those being proposed by the leadership and membership of the RCCAO.

- Finally, there is increasing legal recognition of the rights of Indigenous people in Canada, coincident with rapid growth both in urban Aboriginal populations and First Nations communities. These developments will have a bearing on the future of Canadian infrastructure. Infrastructure to serve remote communities and to access resources in Northern Ontario will be in demand.

- Of equal significance for the shape and timeliness of infrastructure projects will be the enhanced need for consultation, consent and/or community benefit agreements for projects affecting traditional Aboriginal lands. The terms and conditions of such infrastructure will require more negotiation than in the past. It is apparent from past history that new transportation infrastructure can be a welcome benefit to remote Aboriginal communities, but it can also be enormously disruptive. The temporary negative impacts of the Ice Roads in Northern Ontario are an indication of the impacts we can anticipate as access roads are built to serve the Ring of Fire strategy.

- The rapid population growth among indigenous people in Canada will have an impact on the demand for infrastructure investment in First Nations communities and other communities with a significant Aboriginal

population. The widened scope of Aboriginal rights in connection with traditional lands, will make public infrastructure subject to new conditions and timing. It will also be reflected in community benefit agreements to compensate for resource exploitation, which frequently include community infrastructure provisions or to train and/or employ Aboriginal workers and companies. These investments will initially focus on communities in remote locations, including better energy, road and telecommunications infrastructure.

- With increasing out-migration from First Nations reserves and growing urban Aboriginal populations, the future may also see relocating and rebuilding existing remote First Nations communities or their residents to more environmentally and economically sustainable locations, reminiscent of Newfoundland's Outports Relocation program.

E Government Business Enterprises and Public Assets

- In any discussion of financing new infrastructure, or refurbishing or expanding existing infrastructure, consideration should be given to the role that could be played by leveraging existing assets, including government business enterprises and their infrastructure. This would include full or partial sale, leasing, concessions, joint ventures, securitization of cash flows, dividends, mortgaging, collateral security for debt and other tools to leverage our public infrastructure assets.

- As noted, results-oriented regulatory oversight and regulatory restraint will be key ingredients to ensuring that we build and fund the right infrastructure in the future. To some extent, that may entail rethinking rules designed for an industrial age. For example, as an earlier RCCAO study noted, in an increasingly post-industrial society, accounting rules need to evolve, too.[52]

- Governments record the value of land and buildings on their balance sheets, although often at an unrealistic historical acquisition price or book value. But they generally do not assign a sufficient asset value to important soft assets of our digital age: e.g., information assets and databases, the monopoly position of government business enterprises (GBEs) in specific markets, affinity marketing potential, trusted data source, the tremendous research potential of a one-payer public health system, the financial leveraging potential of physical and GBE assets, and so on.

- Data management can also have important value and quality dimensions. While the privacy of personal health information is a principle to which most would subscribe, the way in which we ensure it causes significant gaps in information sharing among health care providers and institutions. Technology offers an opportunity to improve health outcomes, prevent incidents of disease and hospital admissions, and to ensure effective follow-up. But only if we let it.

- Conversely, the impulse and pressure to give away data through well-intentioned open data and freedom of information initiatives can be overwhelming, if their value or impact are not really appreciated or properly accounted. But innovative data miners and "apps" developers will quickly demonstrate its lost opportunity cost to taxpayers. Ironically, opponents of change will be first in line to use FOI access rights to thwart threatening policy innovations or infrastructure proposals with unwelcome local or special-interest impacts.

- **Hydro One and its counterparts:** With changes in electricity generation, transmission and distribution, what is the new business model of traditional major players, like Hydro One?

How should domestic government respond and plan for the future? "… to boldly go where no one has gone before"

How can we embrace the future, if society's agents for change, like governments, are unlikely to be up for the job? We know that simply projecting past practice to resolve unresolved problems is irrational. As Einstein is alleged to have observed: "Insanity is doing the same thing over and over again and expecting different results."

How can we "bravely go" in new directions, when our fidelity to past practice is not producing good results? Star Trek's William Shatner, 84, made this observation in the *Toronto Star*:

> "Every time I come back, I can't find my way." He's particularly alarmed at the tall, dense corridor of condos and hotels flanking the Gardiner Expressway. "It's become cavernous. When I got off the freeway to come downtown, seeing the number of hotels that are being erected in this one downtown area – with the same road system that was horrible before the buildings were built – we're looking at a social disaster." Shatner likened it to the severe drought currently plaguing Los Angeles. "The infrastructure is rotting … Cement is coming off of posts that are supposed to be holding up a freeway that's inadequate before the buildings went up. I don't know who planned anything, but whoever did, it's a disaster."[53]

What is the role of domestic government, versus the role of the private and non-profit sectors, and international governance?

This report has, as one of its main objectives, the goal of assisting decision-makers in the public sector to think ahead about the selection of infrastructure projects, including the factors that will influence those choices, and the consequences of both action and inaction.

One of the factors that this report identified as having an impact on the future of infrastructure is a tendency that the corporate governance sector has come to describe as short-termism. Despite its origin in the private sector, however, it is arguably every bit as big an issue for the public sector.

Elected representatives at the municipal, provincial and federal levels are typically given four-year mandates, at the end of which their contracts are up for renewal by the voters. In 2014, the turnover of municipal councillors and mayors in Ontario approached an unprecedented 50 per cent and many former members of the Ontario Legislature also gave up their seats in 2014. Similar rates of turnover were evident at the federal level, even in advance of the 2015 election call. In that environment, thinking beyond four-year planning horizons can be difficult. Coupled with this constraint is the burgeoning influence of social media and the more generalized "gotcha" style of journalism that focuses the 24-hour news cycle on mistakes, miscues and missed targets.

Infrastructure, on the other hand, is usually a long-term venture. Its gestation period is long, typically with protracted environmental assessment processes and often acrimonious public debates about both the plans and financing. It is fraught with the attendant risk and political embarrassment of being overdue or over budget. The risks now extend to making costly mistakes about the priority, type and location of the infrastructure to be undertaken, as well as triggering ideological debates about various public-private partnership (P3) delivery models.[54]

It is an environment that favours the cautious, along with vague plans, deferrals and periodic reconsideration or course correction, all of which can come at the expense of timely delivery and manageable cost.

Positioning government and society to meet the future

Given the constraints within which modern governments must operate, it is important to provide them with the tools to do the job that they are elected to do. In many cases, this involves compensating for the recognized shortcomings of the existing decision-making system. The Ontario government's use of alternative financing and procurement (AFP) is an example of the measures that can be taken to overcome systemic problems, such as the inability to build major infrastructure on time and on budget, without scope-creep and a myriad of in-progress project change orders.

But construction and financing methods are not the focus of this examination of infrastructure.

Among the challenges facing governments at all levels is getting good advice. While there is no shortage of advice, it is often self-interested or inadequately researched. Particularly in the case of infrastructure projects and systems, among the most active players are those who traditionally undertake infrastructure projects and, conversely, those who perceive their lives, their values or their wallets being adversely affected by such projects.

In the past, when political leaders looked for dispassionate professional advice, they looked to the public service. Public service professionals and policy analysts would explore the options, consult with stakeholders and present a range of viable options, along with a recommended course of action. (Of course, no one would suggest that the past were the halcyon days of professionalism and objectivity. Even with solid professional advice, politics often played an even larger role in infrastructure decisions.) In recent years, however, much of the in-house "policy capacity" of the public service has been reduced through budgetary constraints and by the loss of experienced professionals, who often worked in a specific sector at another stage of their career.

Coincident with the decline in the numbers of experts within government has come what many would describe as a loss of respect for the value of professional expertise and function-specific experience, especially if it represents – in Al Gore's words – "inconvenient truth." General management expertise is often the norm in government, with deep, functional expertise being less frequent than in the past. (In addition, in their 24-hour news-cycle political environment, political staff may not appreciate the value of experience and the long-term view.)

In their place, we have seen the emergence of political advisers and partisan policy advocates, often working closely with those self-interested stakeholders mentioned earlier. While this model can work, it is entirely dependent on the sources consulted and the ability of leaders in government and civil society to interpret (or accept) the technical and policy advice that they hear.

In many cases, external think-tanks, academic experts and industry associations can make a meaningful contribution to discussions that should have both policy analysis and technical understanding. In other cases, ideology, partisanship and well-intentioned rules affecting lobbying can colour or impede the availability or quality of the advice available to public decision-makers. Moreover, for the most part, the focus of these infrastructure discussions is too often short-term in orientation – at least as far as infrastructure project issues are concerned. In this environment, infrastructure policy decisions risk being less evidence-based and lightly researched, in favour of "solutions" that play well in the media, to political constituencies, or to the casually informed.

Developing strategies for the future of Ontario – learning from history

By their nature, infrastructure debates should be broad, wide-ranging, inclusive and long-term in orientation. They do not benefit from time-limited, politically controlled processes and narrow-gauge advice.

At the beginning of this report, we suggested that we cannot drive while looking in the rear-view mirror. There are, however, proven historical precedents that would offer guidance and cautions for today's (and tomorrow's) infrastructure decision-making. One way to bridge the gap between weak in-house capacity in government and the lack of objectivity and short time horizons of external advisers is to look to the models followed by governments in the past.

In the era when much of Ontario's post-war infrastructure was built, the premiers and prime ministers of the day relied on government advisory bodies that were permanent and independent, but with the confidence of decision-makers at all three levels of government and within the private-sector and broader civil society. The Economic Council of Canada (founded in 1963, disbanded in 1992), Ontario Economic Council (founded in 1968, disbanded in 1985) and other similar bodies provided objective, implementation-sensitive, broad-gauge advice to government.

When specific challenges faced governments in the past, Royal Commissions or their equivalents were established. These policy-determining inquiries included the Goldenberg and Robarts Commissions on Metro Toronto (1965 and 1977), the Smith Committee on Taxation (appointed 1962; reported 1968; leading to Ontario's blueprint Design for Development strategies, including regional municipalities and comprehensive tax reform), and the Royal Commission on the Economic Union and Development Prospects for Canada (Macdonald Commission; appointed 1982; reported 1985). One of the earliest and most long-lasting in its impact was the MacPherson Royal Commission on Transportation in Canada, which reported in 1961. Among other things, the MacPherson Commission recommended a market-based business model for railways, opening the door to eliminating passenger rail subsidies (and services), closing unprofitable rail lines, and restructuring grain-handling subsidies (Crow rate). Royal Commissions were supported by able staff, often recruited into government from major firms and universities. (The small Treasury team that supported the policy initiatives of the late 1960s and early 1970s went on to be major figures in government, business and academia.)

Gone are those independent think-tanks and government advisory bodies. In recent years, external advice has been more tailored and more limited in both its mandate and its focus, although they still have an impact, such as the Don Drummond Commission and the Ed Clark Panel.

Perhaps the two most relevant comparisons to the future of infrastructure challenge are Ontario's two largest experiments with what former Prime Minister Tony Blair's U.K. government called a "joined-up," "whole of government" approach. These experiments were Ontario Smart Growth and before that, the Committee on Government Productivity (COGP), led by Harvard professor and entrepreneur-turned-public service executive Jim Fleck.

The COGP was appointed by Premier Robarts in 1969, seeking reforms in the way government worked, so that it could deal with the many challenges facing Ontario at the beginning of the 1970s (many of which

have been recalled earlier in this report). Fleck was executive director of the COGP from its inception to its final reporting out in 1971, following which he was appointed "CEO" of the Premier's Office (1972-73) and then Secretary of Cabinet (1974-75), with the mandate to implement the COGP's recommendations.

The COGP looked to the future needs of the Ontario government, on issues ranging from communications and public engagement, through to synchronizing decision-making across ministries. It resulted in a wholesale reorganization of the Ontario Public Service, into a model that continues (with modification) to this day. One of the challenges it faced was breaking down the silos that separated government departments and deploying modern public sector management practices across a bureaucracy that had remained largely unchanged since the Second World War.

While the COGP reforms succeeded in many respects, one of its notable failures was the creation of overarching secretariats for a number of related ministries, headed by a Cabinet minister. These "super ministers" did not have direct control of the people, resources and programs that make governments relevant, and the super ministers found themselves overseeing the development of plans rather than programs and policies, and politically ineffectual in relation to their colleagues. The "policy secretariats" experiment was abandoned coincident with the reduction in the size of Cabinet in the mid-1970s. As a result, in the management culture of the OPS, secretariats came to be regarded as time limited, boutique ventures at best, with modest, stakeholder-engagement initiatives as their goals.

In 1999, the Ministry of Municipal Affairs and Housing proposed that the province should return to the twin tasks of direct involvement in land-use planning and developing new approaches to building infrastructure. At first, this was not a popular idea, as it was not part of the government's core objectives, and it encroached on the bureaucratic preserves of a number of ministries and in-house OPS professionals.

But the initiative had executive leadership and access to key decision-makers and stakeholders. Borrowing, but modifying a U.S. model, the policy initiative was branded "Ontario Smart Growth." The policy aimed to promote a more whole of government approach to land-use policy and infrastructure investment through the development of plans that would guide ministries and municipal authorities.

The implementation vehicle chosen was unique. Rather than vesting the smart growth program in any one central agency or line ministry, as would be standard practice, or creating an autonomous agency, Cabinet took a new approach. It authorized the creation of a Secretariat in a new ministry devoted to infrastructure, with authority to select staff from across government, many of whom were unburdened by a commitment to past and existing practices. Drawing on a rich collection of outside advisers, serving on panels, the Secretariat developed a regime of initiatives and sponsored others that reshaped the context for land-use planning and infrastructure investment across the GTHA and much of south-central Ontario.

After the election of the McGuinty Liberal government in 2003, the program's close association with the Harris and Eves governments was offset by its evident success and popularity. The new administration rebranded it and built on its successes, with initiatives like the Greenbelt and Metrolinx. With the passage of time, some of the effervescence and autonomy of the smart growth policy has abated, as line ministries and central agencies reassert their policy imperatives, and as economic circumstances call for different approaches. Still, the design and impact of the smart growth/ Growth Secretariat model is worth considering by those charged with implementing a new vision of the future of infrastructure in Ontario.

If governments plan to address the infrastructure challenge in the way that their predecessors built the infrastructure of post-war Ontario, they will need to broaden the tent, extend their planning horizons and work together

inter-governmentally. They will need to invite a broad range of views, but emphasizing evidence-based conclusions, rather than polemics or ephemeral proposals. In the pre-Internet era, the distilled wisdom of those inquiries was also given a high profile and a publicly accessible manner of presentation, adding to their momentum and impact. (Events like the Confederation of Tomorrow Conference, sponsored by Premier Robarts, arguably set the agenda for the evolution of the Canadian Federation and its fiscal bargain for a generation.)

Developing strategies to make Ontario's future – Recommendations

To replicate the policy successes of the past, any ongoing forum or inquiry on future infrastructure will require talented people. Policy-makers must go beyond government to recruit leading figures from business, labour, academia and civil society. They must also resource their efforts with public servants and political advisers who have relevant career experience and who enjoy the confidence of political leadership. Whether hired or contracted, staff may need to be compensated in a manner that reflects the market for their skills and experience.

Infrastructure planning and investment also needs a structure/process that is long-lived and self-regenerating, just as our future infrastructure itself must be. Earlier RCCAO independent research has proved to be a solid foundation for this look into the future, including the February 2009 study by T. E. El-Diraby, T. Wolters and H. M. Osman, "Benchmarking Infrastructure Funding in Ontario: Towards Sustainable Policies."[55] Jurisdictions like New South Wales (Australia), Singapore and the United States (Environmental Protection Agency) point the way to evidence-supported decisions about infrastructure and practical performance measurement of needs and outcomes.

We need to give infrastructure issues an immediate and well-researched profile among Ontarians in general, and among decision-makers in particular. We should revive the concept of a **Royal Commission**, to evaluate policy choices and to make independent but authoritative recommendations to government. We also need to provide a prominent, **annual public platform to showcase** important infrastructure issues.

We also need mechanisms to overcome our siloed, short-term thinking. This report proposes a new, **integrated decision-making structure** for infrastructure decisions by the Ontario government and its partners, by elevating the ministry division responsible for infrastructure to the status of a full-scale, whole-of-government **Infrastructure Policy Secretariat**. This structure would be complemented by a blue-ribbon **Ontario Future Council**, focused on the future of Ontario's infrastructure, to give all of civil society a voice on these issues.

We need to ask Ontario's leaders, in the memorable words of Walter Gretzky, "to skate to where the puck is going to be."

It is evidently difficult to plan for infrastructure networks and projects in the absence of an overarching **economic development and employment strategy** for the province. As with infrastructure, Ontario has the opportunity to look afresh at its economic future and to put in place a plan to anticipate it, shape it and achieve it.

Above all, we need to have the right framework for making Ontario's infrastructure decisions. This report recommends these ingredients for a future of infrastructure strategy for Ontario:

1. In a constrained fiscal environment of capital rationing, governments must both build the right infrastructure, and build it right, with a view to making infrastructure investment decisions based on an **understanding of megatrends**, and using the most **sustainable and forward-looking financial instruments and tax policies**.

2. Appoint a **Royal Commission on Ontario's Future**, with a particular focus on the role that infrastructure can play in creating a prosperous, productive and equitable society, beginning with a broad, **future-oriented economic development and infrastructure strategy**;

3. We need mechanisms within government to overcome our siloed, short-term thinking. Our goals should be a coherent strategy on infrastructure, supported by benchmarking to measure progress objectively. This report proposes a new, **integrated decision-making structure** for infrastructure decisions by the Ontario government and its partners. It begins by elevating the ministry division responsible for infrastructure to the status of a full-scale, whole of government **Policy Secretariat, headed by a Minister and Deputy Minister**. The Policy Secretariat's mandate would be to support the work of the Royal Commission and to take a future-oriented approach to planning and building infrastructure in Ontario, focusing on the policy and performance management issues that must be addressed.

4. The Policy Secretariat should have a budget that would include the capacity to recruit talented staff and **advisers from outside the Ontario Public Service** (with compensation that reflects the norms in their labour market sector).

5. Through the use of research grants, the governments of Ontario and Canada should engage post-secondary and health care scholars, and leading thinkers from the various sectors of Ontario society to address infrastructure issues. Based on our successes in areas like bio-tech, clean-tech, and agriculture/agri-food, and with the Ontario Centres of Excellence, we should recognize the catalytic role that targeted research investments can play. A suite of **"infrastructure innovation" grant funds** could promote future-oriented infrastructure investment and evidence-based benchmarking. In particular, these funds could promote collaboration between municipalities (and Aboriginal communities) and private-sector firms to address identified local challenges.

6. The government should create an ongoing **Ontario Future Council** made up of a cross-section of Ontario's thought-leaders and decision-makers, from the worlds of business and labour, government and academia, traditional and social media, non-profit organizations and broader civil society, led by an executive committee of distinguished Ontarians. A blue-ribbon **Ontario Future Council**, focused on the future of Ontario's infrastructure, would give all of civil society – not just governments – a voice on these crucial issues.

7. Recognizing that large elements of Ontario's infrastructure are under the management and control of local authorities, such as **municipal governments**, the proposed Ontario Future Council and the Secretariat should take specific measures to ensure that this order of government is a full and equal partner in these discussions, including subsidizing the cost of their participation;

8. In light of the recognition of the rights and interests of **Indigenous people** in Ontario, including specifically **Tribal Councils of First Nations**, the proposed Ontario Future Council and the Secretariat should take specific measures to ensure that this order of government is a full and equal partner in these discussions, including subsidizing the cost of their participation;

9. An early, high-profile and annually repeated **conference event**, led by the Ontario Future Council, to highlight the issues facing Ontario's "infrastructure future" and to enlist the interest and involvement of Ontarians; and,

10. Reflecting the changing world in which public decision-making about the future should be made, the ongoing work of the Policy Secretariat and the Ontario Future Council should be enriched and motivated by a **robust online consultation**. That consultation would explore issues using a wiki-based, open-dialogue format and a policy options analysis process to examine risks, opportunities and creative solutions.

CONCLUSION

We are on the verge of spending billions on infrastructure, in Canada and across the world. Few issues now enjoy such universal support across the political spectrum. Major projects are attracting substantial government support, investors and pension funds are eager to invest, and governments see infrastructure needs being financed at historically low interest rates. What could possibly go wrong?

Infrastructure lasts a long time. The impact of infrastructure is felt by everyone, and for decades. In an era of unprecedented technological, economic and social change, few decisions depend more on being able to see clearly into the future than decisions about infrastructure. As Canadians, we know that infrastructure helped create our coast-to-coast future in the 19th and 20th centuries. It will also underpin our prosperity and quality of life in the 21st century.

Adopting a meta-analysis research model, this report surveyed the opinions of leading thinkers in technology, social policy, demographics and economics. They had this in common: they believed a few megatrends – the emerging patterns and developments that are sweeping the world and changing the way we live – will have great relevance for the future of Ontario's infrastructure.

Using this meta-analysis approach, this report looked at a wide variety of sources for ideas on those trends that we will face as a society in Ontario, and how those trends will affect the infrastructure of the future. This report has identified six important megatrends that will determine the future of Ontario's infrastructure and its effect on Ontario society and its economy: (1) the nature and pace of technological change; (2) globalization, urbanization and connectivity; (3) social and demographic trends, including health care and social policy; (4) economic and workforce trends; (5) environmental and energy trends; and (6) political and fiscal trends.

From a large array of possibilities, the study distilled 11 planning assumptions or guiding principles that should guide Ontario's infrastructure decision-making into the future. These principles will determine not only the type of infrastructure we may see in the future, but also the way in which that infrastructure may affect Ontario's economy and society in the future.

In a constrained fiscal environment of capital rationing, governments must both build the right infrastructure and build it right, with a view to making infrastructure investment decisions based on an understanding of megatrends, and using the most sustainable and forward-looking financial instruments and tax policies.

The impact of specific megatrends on infrastructure – Guiding Principles

Next, the study moved from the theoretical to the practical. The collected research and these guiding principles were synthesized and applied to specific categories of infrastructure, both current and future, to paint a picture of future possibilities. Four detailed appendices complement the analysis.

Infrastructure is all about technology. So it is not surprising that one of the biggest megatrends affecting infrastructure will be the **pace of technological change**. Infrastructure is also the nervous system for **urban design** and **connectivity** (both between countries and between people), so it will produce new models of daily life. The impact of **globalization** will cause infrastructure to play a more global role than ever before, across the Great Lakes Region and, indeed, around the world. **Connectivity** will also be the fulcrum for efforts to converge technology, in order to make more efficient use of infrastructure. The aging of our society and the impact of immigration will yield **social and demographic impacts** on infrastructure, ranging from the way we educate our children to the way we care for our parents.

As infrastructure responds to the **evolution of Ontario's economy** and, in some cases, determines the direction of that evolution, there will be impacts on Ontario's **workers and the workplace**. Of equal weight, as energy and climate change continue to grow in importance and their impacts become more conspicuous, **environmental and energy trends** will affect infrastructure's scale and design, in areas from stormwater and wastewater management, to solid waste and recycling, through to the design of homes and vehicles.

Finally, with the potentially unprecedented volume of new and expanded infrastructure, and the financial demands it creates, there will be significant impacts on **fiscal policy**, affecting both the **funding and financing of infrastructure**. **Political leadership**, often focused on the near-term and traditional, project-specific infrastructure, will face the challenges of trying to anticipate the **changes that new infrastructure will bring**. An even greater political challenge may be **winning public support for a coordinated approach** from a populace that faces the future with equal measures of fear, uncertainty and skepticism.

Using those megatrends as a compass, the study distills a number of **"operating principles"** or assumptions. They can be used to gauge and

guide our approach and response to developments in the major fields of infrastructure, from transportation to telecommunications to health care. Of course, many of these operating principles do not operate in isolation from one another. They produce synergistic effects that cannot readily be anticipated.

Distances and elapsed times will shrink, both from new infrastructure and from changing the way existing infrastructure works. Integration and miniaturization will cause **scale to shrink** and separate **functions to converge**, regardless of their previous ownership and management patterns. At the same time, in building, operating, managing and disposing of public infrastructure, the imperatives of e-business, low transaction costs and the local manifestations of global competition will cause **margins to be squeezed**, with impacts on labour, procurement, productivity improvement and operational efficiency.

As infrastructure moves from wholesale to retail, technology-enabled **individual customization** will come to be expected by consumers, whether they are patients, passengers, pupils or product producers. **Global impacts** will find themselves playing out in the local context, whether accelerating levels of population migration, or selling/sourcing goods and services to and from the other side of the world. Among these global impacts will be the **effects of climate change**, with their often-unpopular implications for more costly stormwater management, reduced automobile fuel consumption, promotion of greater building density, and higher clean energy and food costs.

Some of these impacts will combine to create a market for new, **consumer-driven urban designs**, suited for market niches, like aging seniors or families unable to afford metropolitan housing prices. **Demographics** will alter society's priorities. With those new priorities will come changes to the models of infrastructure that have traditionally served society, such as hospitals, recreational facilities, penal institutions, transit systems and college campuses.

All of these changes share a common feature: they need to be anticipated by decision-makers – accurately and well in advance. But our 24-hour news cycle, the expectations of market analysts, and the impact of the blogosphere, Twitter and Facebook increasingly drive our political, business, labour and civil society leaders to the short-term time horizon and the here-and-now. **Short-termism** is not only a threat to business performance and environmental sustainability: it makes effective infrastructure planning very difficult and prone to greater risk of waste, misdirection and system failures. The rigorous, evidence-based, collaborative infrastructure planning and implementation seen in jurisdictions like New South Wales, Singapore and even the U.S. Environmental Protection Agency appear to have made real progress in overcoming short-term thinking and unsustainable practices.

With the convergence of miniaturization, pre-constructed components and new building materials, the infrastructure of tomorrow will include more **light infrastructure**. It will have a shorter life expectancy, new materials and designs, more capacity to be adjusted to meet changing demographics, economics and use patterns, and with a lower community impact and price tag. (Transit, for example, will look to the experiences of the Docklands Light Rail or York Region's BRT network for practical, lower-cost and more flexible responses to evolving commuter needs.)

Paralleling light infrastructure is the retrofitting and re-purposing of existing infrastructure, to increase its resilience, its through-put or its life expectancy, as an alternative to the daunting task of securing approval for major new heavy infrastructure projects, networks and utility corridors.

The next generation of infrastructure will feature **long-distance commuting**. Both workers and providers of business services will expect to be able to move considerable distances regionally, rapidly, conveniently, frequently, safely and at low cost. As many more Ontarians will be self-employed and seeking trade where they can find it, they will want to be able to serve a much wider market area. As housing prices rise in major centres, Ontarians may want to live in one city and work in another, as other family

members travel from home in other directions for work or study. These are commuting patterns that will shatter our traditional hub-and-spoke transit and transportation models, in which we have continued to invest so heavily. These new commuting patterns are an example of the **individual customization** that will be a feature of the new infrastructure.

We will need to **think globally, but act locally**. Innovations from elsewhere will be adopted here, and the study cites a number of intriguing examples.

Many public and community functions will converge, with the result that traditional segregations will make less sense. **Convergence of infrastructure** will sweep away customary but wasteful distinctions, like those between school systems, or the segregation of police, courts, incarceration and release-monitoring facilities solely for reasons of juridical appearances. Most conspicuously vulnerable to convergence are the distinctions based primarily on administrative geography, ownership, trade-union jurisdiction and so on.

The use of universally accepted, bank-affiliated, smartphone-based, multi-purpose transit fare-media will drive convergence in a range of transportation areas. These applications will include: integrated distance-based fare regimes for local and regional transit; on-street and off-street parking location and fee-paying; new formats for taxis and taxi alternatives, including ride- or vehicle-sharing services like Uber, Car2Go, AutoShare and ZipCar; and RFID-triggering of intelligent transportation networks, way-finding and GPS guidance, and other in-transit applications, like paying for convenience incidentals (coffee and lottery tickets).

Another manifestation will be the wider use of Ontario-pioneered transponders for automobile pay-by-distance road-use, HOT lanes, automobile insurance applications and aggregated traffic management data for use by civic authorities.

As the **demographic challenges** facing the labour market intensify, our population will see increasing diversity. In the future, foreign immigration will reflect our need for the skills and innovative drive of offshore talent and,

realistically, to address the personal caregiving needs of an expanding and long-lived frail and elderly population. Given the global migration pressures of war and poverty, we may also be increasingly affected by the pattern of informal foreign immigration seen in Europe, the U.S. and South Africa.

Shrinking distances and turnaround times, and converging functions, will alter the lives of those who work in and with infrastructure. Workers will increasingly find that they can (or must) live far from their workplace or worksite. As infrastructure incorporates more sophisticated materials and technologies, the need for continuous training and education will also increase. The rapid evolution of robotic technology may have the kind of impact on construction and home-building industries that it has already had on manufacturing, the service sector, telecommunications and primary industry.

The demands for reduced marginal costs will put pressure on those engaged in building and operating infrastructure, from collective bargaining to increased use of pre-assembled or shrink-wrap approaches to installing and maintaining infrastructure. Pressure will be felt to reform traditional controls on new entrants to the workforce and to reevaluate the criteria for recognizing international qualifications, and professional and trade certifications.

The growing interest in creating a **Great Lakes marketplace for infrastructure projects** will favour Ontario's companies and workers. But only if we anticipate the needs of the next generation of infrastructure. We may need to remove some of our self-imposed restrictions on awarding contracts and labour mobility. Convergence will confront the workplace. As the traditional distinctions between types of work blur, distinctions in job descriptions and classifications will become less meaningful.

There will be an impact on work from the inevitable shift in the kind of projects being undertaken, both large and small. In those areas where major public institutional jobs, big residential developments or large-scale

engineering works will be less common, the focus may shift to refurbishment, decommissioning, re-purposing and ongoing service contracts. A multiplicity of small-scale projects may fill the order books of firms that used hires for long-term, single-site projects. In some cases, skills learned in one sector may need to be modified and applied to jobs in a new, related field of infrastructure.

Foreseeable futures in infrastructure

The transportation infrastructure of the future will see more intelligent transportation systems (automated vehicle control, driver-assisted vehicles, road-pricing regimes, in-vehicle technology for distance-separation and collision-avoidance, expressway system-access controls, intersection re-design, etc.) and computer-aided logistics and dispatch, from supply-chain to way-finding and ride-sharing. (See Appendix B.)

Rapid transit and public transit will see platform-side doors, automated train control, and time-of-day and distance-sensitive fare-media. Major urban centres will require much broader and more integrated regional transit and transportation infrastructure planning than has been the case in the past. Some major roadways will be funded directly by road-pricing measures, beginning with technology-enabled tolling of driver-only cars using high-occupancy vehicle (HOV) lanes.

Technology will come to the rescue of the mounting problem of deferred maintenance obligations in waterworks, roadways and other public infrastructure, which now also burden the financial balance sheets of municipalities and public agencies. Nano-sensors built into roadways, bridges, parking garages and under-road water and sewer networks, along with the expanded use of monitoring/inspection technology, will enable a more targeted, no-surprises approach to maintaining existing infrastructure.

Freshwater transport throughout the Great Lakes has a bright future in inexpensive, environmentally beneficial international and domestic shipping of bulk commodities, agricultural produce and other goods. However, it also faces physical, commercial and regulatory challenges.

In the future, transit-service infrastructure decisions should not be made primarily with a close eye to municipal boundaries, restrictions in collective agreements, protecting fare revenues, or local or regional system ownership (including public vs. private). Integrated fare-media using smartphones and RFID credit cards will allow passengers to decide where they will park, which transit infrastructure they will use (including private options) and ultimately, where they will travel. These patterns will drive transportation planning.

In the field of energy infrastructure, environmental pressure on U.S. coal-fired electricity generation will create business opportunities for Canadian surplus clean energy electricity generators, like Bruce Power, OPG and Hydro Québec. However, next-generation solar energy production may radically alter the economic value of conventional power generating capacity.

Telecommunications infrastructure will be supplemented by expanded use of closed-circuit television systems and infrastructure related to monitoring and intercepting telecommunications and radio-frequency identification (RFID) electronic signals for a wide variety of personal, household, business and public security purposes. Mobile communications are exploding, as is the demand for higher speed, higher capacity Internet and broadband networks. Cable networks and fibre-optics depend on a reliable consumer base. The growing pattern of households in English-speaking Canada abandoning cable television and the next generation's wholesale discontinuation of residential landline telephones have major business implications for builders of telecommunications infrastructure.

Ontario communities have long resisted expansion of landfill sites for solid waste disposal, and in particular, energy-from-waste incineration plants. But energy-from-waste facilities are increasingly using advanced technologies to mitigate real and perceived environmental and health problems.

Extreme weather events and other climate-change impacts will expand the scope of infrastructure related to mitigation and rapid recovery from wind, rain and ice storms, and from power outages, flooding and sewer backups

(both sewage and stormwater). We will also see proposals and mounting pressure to transport some of Canada's abundant (and often shared) freshwater resources to the drought-parched areas of the U.S.

Climate change threatens to change precipitation patterns, and may reduce the ready availability of fresh water supplies in various locations around Ontario. Other factors also impinge, such as our society's tendency to chronic under-investment in potable water systems and to abuse low-cost, conveniently available water supplies. Fortunately, smart metering infrastructure and variable pricing for water and energy have demonstrated a capacity to alter consumer and industrial behaviour. UN initiatives, supported by the Clinton and Gates Foundations, may also bring Ontario new technologies and new management models to related areas, like the collection and treatment of wastewater and the increased use of greywater.

In the future, building techniques and building materials will be asked to address a range of needs, beyond current LEED standards of sustainable accommodation and energy conservation. Building shells and paved surfaces that respond to environmental considerations, like smog-reduction, energy-generation or rainwater-preservation, will become more common and may be required by building codes.

In the fields of social and health infrastructure and policy, the trends will overwhelm our current approaches. The prospect of governments building long-term care homes, palliative care wards in hospitals and similar infrastructure for a whole generation of Baby Boomers appears unsustainable under the present fiscal circumstances. Technological and medical measures to maintain the elderly in their own homes and in retirement residences will expand dramatically.

In Ontario, the cost of publicly funded health care consumes nearly half the annual operating budget of the province and is arguably a major contributor to Ontario's deficit and debt levels over time. With the impact of demographic

trends and new medical technology, these costs will continue to rise. Health care is a primary target for convergence of infrastructure. Ontario needs to meet the evidence-based test of "right treatment, by the right provider, in the right place, at the right time, for the lowest cost to the taxpayer."

Despite our investments and progress in areas like diagnostic imaging and laboratory testing, we still do not have easily transferrable electronic medical records and electronic health records. And personal health data is neither intelligible nor conveniently available to the patient and family caregiver. In Ontario, it has been observed, we all have more electronic information about our cars and our cats than we do about our health.

Serving a growing and aging clientele in their homes and in community settings often achieves better health results, as well as being far less expensive and more time-responsive than the costly institutional alternatives. Good medicine, it appears, is also good fiscal policy. Integration of health care delivery is the key. Our infrastructure investments and funding policies should anticipate, facilitate and support those right choices. It will mean less emphasis on hospitals, and more attention to community health facilities of various kinds, both public and private. In the future, outside of unserviced areas, Ontario may only need to build or expand hospitals for advanced treatments and research.

Throughout the educational system considerations of quality, delivery cost, individual pace, child safety and convenience may accelerate an emerging shift in teaching and learning to telecommunications-enabled settings, which may favour smaller format local learning centres in "community hubs." At the post-secondary level, as MOOCs and TED Talks demonstrate, the world's best professors and researchers can be accessed at times and in settings that best suit an individual student, at a fraction of current costs and with a global scope and the potential for global interaction. These developments have significant implications for investments in university and college campuses, research facilities and student residences.

America's 40-year experiment with high levels of incarceration has demonstrated that prisons are neither cost-effective, nor socially effective. New solutions will have significant implications for infrastructure-intensive public services, like prisons, courts and police services, as they are put through an unfamiliar return-on-investment or pay-for-performance tests.

Homelessness and lack of housing affordability impose disproportionate demands on the public purse in policing, health care, shelter costs and income support. The costs and investment potential of public housing realty assets will drive new, more innovative solutions to housing affordability for the disadvantaged, including physical infrastructure ideas like those being proposed by the leadership and membership of the RCCAO.

Rapid population growth among Indigenous people in Canada will have an impact on the demand for infrastructure investment in First Nations communities and other communities with a significant Aboriginal population. The widened recognition of the scope of Aboriginal rights in connection with traditional lands will also make public and private infrastructure subject to new conditions and timing.

In any discussion of financing new infrastructure, or refurbishing or expanding existing infrastructure, we must look to leveraging existing assets (asset recycling), including government business enterprises and their infrastructure. This would include full or partial sale, leasing, concessions, joint ventures, securitization of cash flows, dividends, mortgaging, collateral security for debt and other tools to leverage our huge past investment in public infrastructure assets.

Governments record the value of land and buildings on their balance sheets at book value, although often ignoring the value of their redevelopment potential. But they generally do not assign a sufficient asset value to important soft assets of our digital age. These include: information assets, patentable processes and databases; the monopoly position of government business

enterprises (GBEs) in specific markets (e.g., liquor and gaming); affinity marketing potential; the government as trusted data source; the tremendous research and procurement potential of a one-payer public health system with 13 million members; the financial leveraging potential of physical and GBE assets; and so on.

The role of governments – an action plan

One of the key conclusions of the report was that the historic and visionary **role of government**, to guide, to lead and to manage the evolution of infrastructure, has been eroded by short-term orientation. In addition, in our increasingly complex society, we have seen the growth of a sectoral approach to infrastructure that threatens to miss opportunities for integration and synergy, due to fragmentation in governance and silos within government and industry. The report concludes with a call for governments at all levels to return to their traditional leadership role of coordinating long-term planning and investment in infrastructure, through collaboration with the major players from business, labour and other elements of civil society.

Finally, this report suggested some practical ways in which governments at all levels, and other leaders of civil society can collaborate and plan, in much the same way as previous generations did in giving us the infrastructure and the economy from which we all benefit today.

The specific recommendations for government action fall into three categories:

First, we need mechanisms to overcome our siloed, short-term thinking. The report proposes a **new, integrated decision-making structure** for infrastructure decisions by the Ontario government and its partners, by elevating the ministry division responsible for infrastructure to the status of a full-scale, whole-of-government **Policy Secretariat**. This structure would be complemented by an ongoing, blue-ribbon **Ontario Future Council**, focused on the future of Ontario's infrastructure, to give all of civil society – not just governments – a voice on these issues.

Second, there is also need for research and evidence to guide our decision-making and to produce innovative ideas, including public engagement using contemporary technology. In particular, a program of **"infrastructure innovation" grants**, funded by the governments of Ontario and Canada would help to achieve this goal.

Third, we need to give these issues an immediate and well-researched profile among Ontarians in general, and among decision-makers in particular. The proposal is to revive the concept of a **Royal Commission**, to evaluate policy choices and make independent but authoritative recommendations to government. We also need to provide a prominent, **annual public platform to showcase** important infrastructure issues.

Overall, governments must build the right infrastructure and build it right, with a view to making infrastructure investment decisions based on an understanding of megatrends, and using the most sustainable and forward-looking financial instruments and tax policies.

APPENDIX A

A Futurist's View of the Seven Megatrends That Will Affect Tomorrow's Infrastructure

by futurist Richard Worzel, C.F.A.

Infrastructure is the set of systems that supports our way of life and includes things like roads, transit, water and sewer systems, communications, electric power, garbage disposal, health care, housing, the penal system and education.

It is a subject totally lacking in sex appeal yet absolutely necessary for our lives.

In this commentary, which was commissioned specifically for RCCAO, I will provide my findings on those forces that will affect infrastructure most profoundly over the next 20 years and beyond, plus my assessment of what some of those effects will be, and how they might be considered in infrastructure planning. Note that these views are my own, and do not necessarily represent those of RCCAO.

As the human race has changed, so have the systems we need for our societies and ways of life. We no longer need caves, horse stables in every town or extensive canal systems. Our infrastructure needs have changed and continue to change. And now, with the light-speed acceleration of technology, the changes coming to the Earth's climate, and the unprecedented aging of society, we and our governments need to respond more quickly and to think differently about infrastructure than we have in the past.

As well, we have seriously neglected investing in infrastructure in the past, and will be forced to make up for it, whether we like it or not. According to an article published in the *Globe and Mail* in December of 2014, Canada has an infrastructure deficit of between $350 billion and $400 billion.[56]

Deciding what infrastructure to invest in, when to make such investments, and how much to invest are all difficult decisions, but they all have one common element which can simplify such decisions: they can all be rendered in financial terms. Making an infrastructure investment has a cost associated with it, plus an expected rate of return to society. (Or alternatively, not making such an investment imposes a cost on society, which can also be measured or estimated.)

Where the rate of return is greater than the cost, the investment should either be made, or the government involved should provide a clear explanation why it is preferable to pay the higher cost of not making the investment. In the present, low interest-rate environment, the cost of investing is probably about as low as it is likely to get, which means we should be aggressively pursuing infrastructure investments right now.

The likely direction of interest rates in the future and the steadily rising costs of delaying infrastructure investments clearly indicate that now is a better time to make such investments than later.

But what else about the future will affect infrastructure decisions?

The seven megatrends

With the changing needs for, and forms of, infrastructure in mind, I would identify the following megatrends that will affect infrastructure investing in Ontario's future:

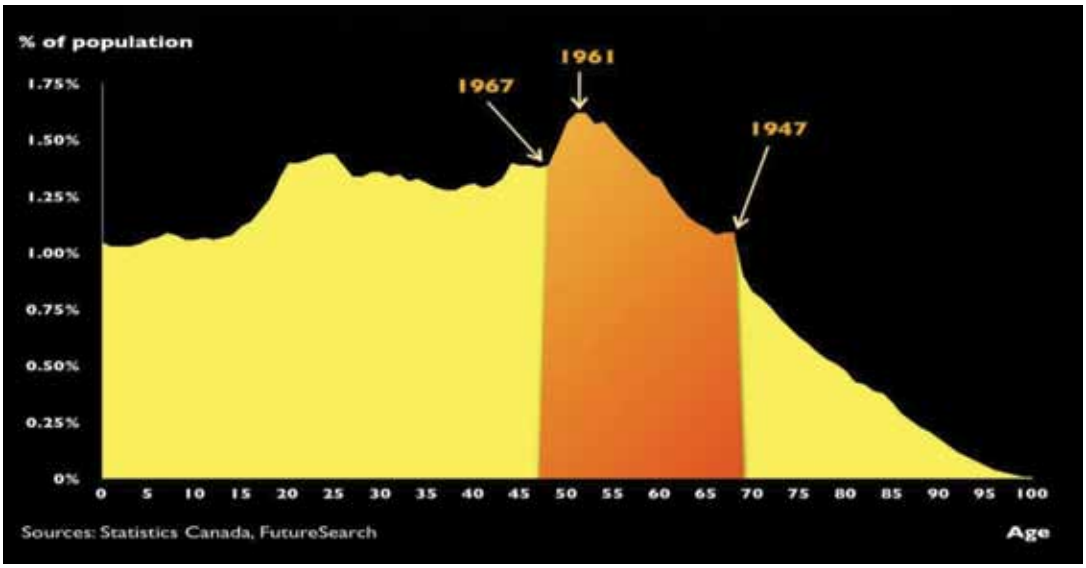
- **Demographics –** An aging population has many implications, some of which are daunting.
- **Technology –** We'll be able to substitute technology for earlier, more expensive solutions, as well as do things that were never possible in the past.
- **Climate change and environmental degradation –** Mother Nature's bills **always** get paid. We must plan accordingly.
- **The global economy –** The continuing emergence of a unified, world-wide economy has major implications for Ontario, especially in education.
- **Human longevity and health management –** While related to demographics, this factor has major implications that go much further.
- **The widening tears in the fabric of society –** The rising costs of the penal system, plus the rise of homelessness, unemployment and underemployment, have significant implications for Ontario.
- **The rapidly mutating job market –** Lifetime employment is long gone, and the future is ever more uncertain, with major implications for society, the economy and infrastructure funding.

Demographics

In many ways, demographics determine destiny. Their measurement is not the only force that drives change in our future, but it is the central one. After all, you can't have an economy without people.

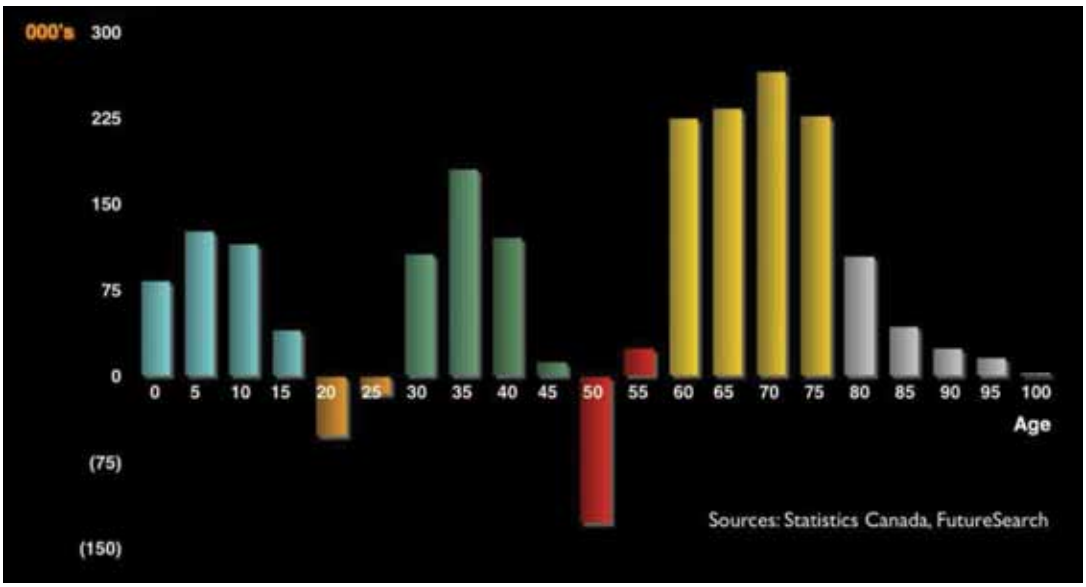
There are many implications of demographics that will affect the province of Ontario and its needs for infrastructure. Let's start with a demographic profile. The first graph, below, shows the current population of Ontario, distributed by age. The big hump highlighted is (by my definition) the Baby Boomers, who are currently between ages 48 and 68.

Ontario Population – 2015



The second graph shows how Ontario population age groups will either increase or decrease in size over the next 10 years. (The groups shown are five-year age groups: 0-4 years old, 5-9 years, 10-14 and so on.) Hence, the 70-74 group will increase by roughly 265,000 between 2015 and 2025, for instance.

Change in Number of Ontarians by Age Group (2015 to 2025)



What this means is that while several groups will increase in size, such as young children, and 30- to 45-year-olds, the biggest change is going to be the Baby Boomers moving towards retirement age.

These changes have some clear implications for infrastructure:

- We will need more schools (but, as I'll point out later, most of these needs will be near the major urban centres).
- Millennials will be moving into the family formation stage of their lives, which means they will need all of the community infrastructure appropriate to young families, including playgrounds, pediatric care, and the ability to get to and from work, which can be some combination of roads, public transit and bike trails. At the same time, most of them probably won't be able to afford homes in the downtown areas of the major urban centres, particularly Toronto, and so will move farther and farther into the suburbs.
- The number of retired and elderly is going to grow faster than at any time in history, which means the needs of the elderly are going to overwhelm virtually all other infrastructure needs. This is due to three overlapping trends: greater life expectancy; the growing number of "oldest elderly," being people 80 and up; and the aging of the Boomers. Combined, this makes people 65 and up the fastest growing group in the population. And they are politically potent, more or less getting anything they vote for and defeating anything they vote against.
- Where the Boomers choose to retire is going to have a huge impact on communities, transportation and social services. Some will stay in their family homes for a time, usually in urban centres. Some will sell their family homes for something smaller in other parts of those same urban centres. And some will move to smaller communities, partly in order to harvest the funds tied up in their houses. What we don't know, at this time, is how many Boomers and the choices they will make.

- The costs of health care for the Boomers are going to dominate government finances, eating into funds for all other government activities. In terms of infrastructure, it means that the government of Ontario is going to have to choose wisely which infrastructure it chooses to underwrite, find cost-effective ways of encouraging others to build infrastructure without government money, but without costing Ontario residents unreasonable amounts of money (think of Hwy. 407). Intelligent, outcome-driven planning is going to be critical.

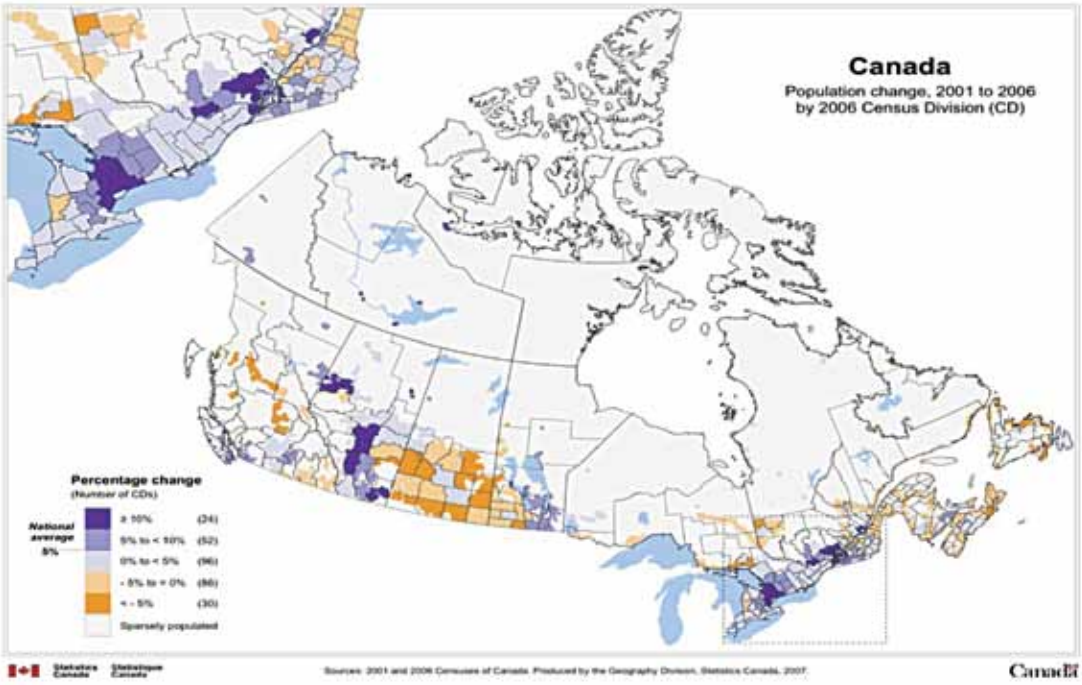
- What is not shown, but is implicit in the graphs on pages 113 and 114 is immigration. Among large, developed countries, Canada has one of the highest immigration rates and one of the highest proportions of first-generation immigrants. As immigrants overwhelmingly tend to settle in the major urban centres, this means that a disproportionate amount of Ontario's population growth will be in and around the major urban centres, especially in the Golden Horseshoe. This implies continued sprawl and problems with affordable housing, not only for immigrants, but also people born in Canada who are in the household formation stage of their lives.

- Contrariwise, Aboriginal peoples have the fastest population growth among non-immigrant Canadians. As such, they should represent a steadily increasing percentage of employed citizens in Ontario society. However, that can only happen if the health, education and living conditions of First Nations, Inuit and Métis peoples are significantly improved. Moreover, the recent Truth and Reconciliation Commission of Canada report clearly shows a social and cultural imperative to make good on generations of mistreatment and neglect by Ontario society and government, along with the other provinces, territories and the government of Canada. Consequently, projects related to the infrastructure needs of such groups should be placed higher on the political agenda than they would otherwise be. It's time, and past time, that Aboriginal needs were pushed up, rather than down, in priority.

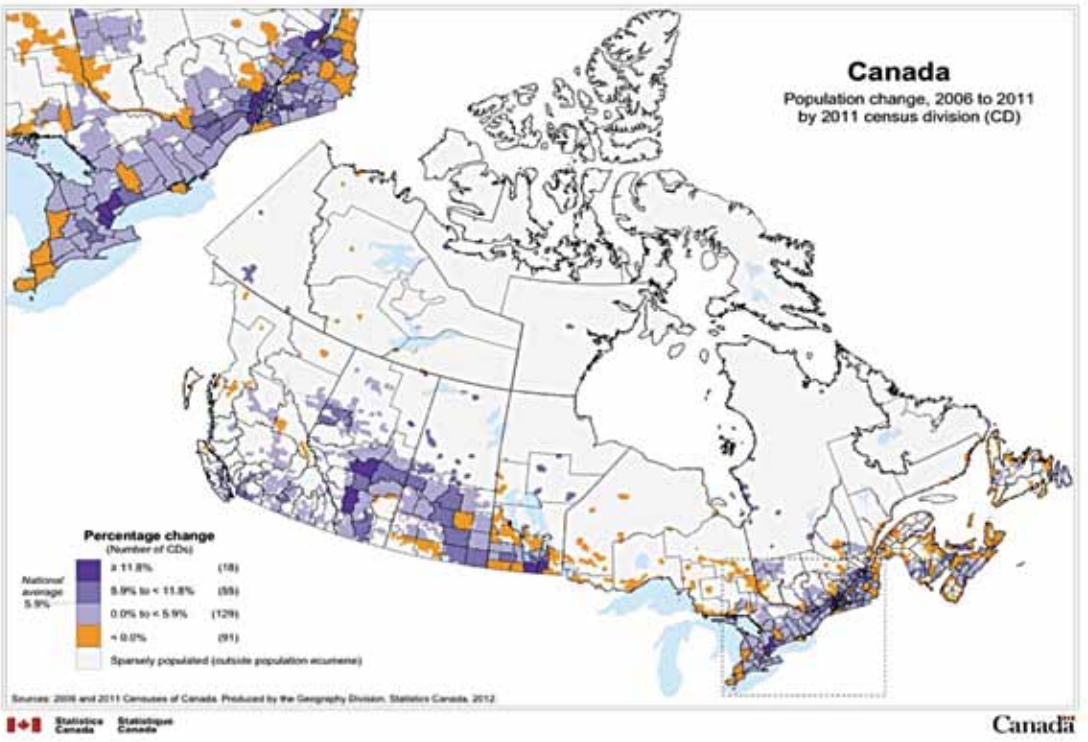
Another important aspect of demographics is **where** people will want to live. For more than a century, people have been leaving the rural areas of the world and moving into the urban centres. This megatrend continues unabated and, if anything, has accelerated here because of Canada's immigration policies.

All of this implies that there will be more demand for infrastructure in Ontario's cities – especially in the GTHA – and less in the exurban and rural areas of the province. This is evident from the following census maps produced by Statistics Canada.

Change in Population between 2001 and 2006 Census Tallies



Change in Population between 2006 and 2011 Census Tallies



This movement away from exurban areas could leave a lot of towns and smaller municipalities unhappy with the way the government of Ontario allocates infrastructure funding, especially as such funding becomes scarce. This may, if not provided for, lead to ineffective choices being made for projects that have a much higher political value than real value to the citizens of Ontario.

Consequently, an objective means of setting infrastructure investment priorities will be needed to identify the most important – as opposed to the most politically attractive – infrastructure investments. An independent assessment of the rate of return vs. the cost of each project would offer such an objective measure.

The continuing in-migration to the cities will also create steadily worsening bottlenecks. The 400-series highways, and especially those going into the major cities, are already heavily clogged with trucks bringing all the goods and products needed to support city dwellers. Train and pipeline transport, especially of hazardous substances, must grow to support urban populations, but they are being widely opposed because they are perceived as being too lightly regulated and therefore dangerous.

Urban populations are going to continue to grow, and in areas already heavily developed. As a result, the volume of truck, rail and pipeline transport heading into and supporting the cities will also swell. The increase in truck traffic, added to the volume of commuters heading into work, is going to make gridlock and bottlenecks worse and, in some places, impossible. This will be particularly evident – and difficult – in the GTA, where population is projected to grow by almost three million people to 9.4 million by 2041.[57]

More roads are probably not the answer as there is often no room for additional or expanded roads. New and often unpopular choices will be necessary, such as congestion tolling, which is spreading among major urban centres around the world and has been shown to work. And drivers must be given workable alternatives to encourage them to leave their cars. Here we should draw on the experiences of congested, cramped, densely populated parts of Europe, where rapid transit and bike lanes are created as parallel infrastructure systems in order to allow the largest number of people to move with the smallest possible footprint.

One partial solution will be to encourage the development and use of telecommuting by GTA businesses. As wireless and high-speed Internet technologies continue to develop, and as online conferencing tools become more sophisticated, this may allow GTA businesses to grow while requiring less frequent commuting by workers.

Alternatively, planners could find ways of encouraging a greater decentralization of activity, spreading the commuting load around the major centres rather than continuing to find ways to funnel more people into relatively concentrated areas. This might mean promoting U.K.-style "new towns" supported by low-cost, high-speed transport, and offering more affordable housing outside of core areas. The intra-regional transit plans in place in the GTHA are an important step in that direction, but more would need to be done.

What will almost certainly break down in the next 10 years and beyond are the attempts to shoehorn ever more workers into Toronto's downtown core, which has already created costly and exasperating traffic congestion. If that pattern is difficult now, with approximately six million people in the GTA, it will become impossible as the region grows to more than nine million. New solutions have to be found through a variety of means.

Technology

Technology will be both a blessing and a curse for infrastructure planners. On the one hand, it will offer the possibility of new, more cost-effective solutions. Among these might be:

- Remote, smart sensors may mean that visits by seniors (and others) to doctors or hospitals, or visits by nurses to those needing health care in the home, may be significantly reduced. Indeed, I would contend that future advances in health care technology should be seriously studied as an alternative to new hospitals.

- Autonomous vehicles (self-driving cars and trucks) may – over time – significantly reduce the number of additional roads required to support population growth in the urban centres. Moreover, self-driving trucks may become more widely used late at night, arriving to make deliveries before commuters seek the roads.

Driverless cars may also be much more efficient at moving through traffic. They could be able to consult with other cars, and a region's traffic computer about the best route from A to B, diffusing congestion and lowering the amount of time – and hence number of cars – on the road at any given time.

Autonomous vehicles (AVs) may also significantly lower traffic collisions, injuries and fatalities. This would lower the number of emergency vehicles and crews required and reduce medical expenditures. Such vehicles may also significantly reduce traffic violations – and revenues.

But I keep saying "may" and "would" rather than "will" because AVs require a major changeover, both in the way we do things, and in the infrastructure necessary to support these new ways. As well, the mix of AVs and human-driven cars on the highways will significantly affect how much savings there will be. A roadway completely devoted to self-driving cars will have a substantially greater capacity than one with 10 per cent human-driven cars, because those driven by people will require all vehicles to allow more space and affect the rates of speed and acceleration. A complete changeover is unlikely to happen quickly.

- As aforementioned, telecommunications continues to grow and expand, and its importance will grow apace. Indeed, it is no longer a frill for early adopters, but is now an absolute necessity for almost everyone engaged in the economy, as well as for most people in society.

  To date, Internet access has been provided almost exclusively by private sector suppliers. However, the importance of widespread, fast Internet service is too important to be left only to a private sector oligopoly. They will almost certainly remain the backbone of Internet service, but other alternatives are emerging that should be considered, and which may provide a spur to private sector offerings.

Chattanooga, Tenn., created an Internet infrastructure through their municipal electric power utility almost as an afterthought in the construction of a smart power grid. "The Gig," as it's called, offers residents and businesses Internet speeds of one gigabyte per second – or about 50 times faster than the U.S. national average. As a result, "Chattanooga has gone from close to zero venture capital in 2009 to more than five organized funds with investable capital over $50m in 2014 – not bad for a city of 171,000 people."[58] And, predictably, cable and telecom Internet service providers are petitioning the U.S. Federal Communications Commission to block such developments.

- Elected officials in Ontario's exurban areas are anxious to see broadband extended to their communities. "Building broadband is as important as paving roads and building bridges" one leader was cited as saying.[59] And the $170-million Eastern Ontario Warden's 4G broadband initiative, which is a P3 project involving federal, provincial and local governments, is one example of how such services might evolve.

  Fast Internet service can provide important tools in a wide variety of applications, and many sectors of the economy. Telecommuting has been mentioned. Distance education will be discussed below. Telehealth is a rapidly expanding field that can help stretch scarce resources in the health care system. Moreover, new applications always emerge from more powerful communications tools that can add significant value to Ontario's economy, and make it more attractive as a place to do business – just like in Chattanooga.

- Computer monitoring systems, notably Fog computing[60], may allow us to identify pipeline breaks almost immediately, and dispatch crews to fix them before they cause significant damage. This could not only allow leaks in oil pipelines to be identified early, but also in water, stormwater and sewage pipes. At the moment, an unknown but significant percentage of the water piped to Ontario residents is lost due to leaking underground pipes.

- Three-dimensional printing[61] is a commonly used phrase to describe a range of different technologies that will be as revolutionary in the real world as the Internet is in the virtual world. These technologies will have some obvious effects, such as changing some parts of the manufacturing industries from mass production to mass customization, or eliminating some mass production in distant locations in favour of local production. But it will also have more subtle effects, such as changing distribution industries, like shipping, trucking, rail transport and last-mile delivery services. Hence, the plans for an object might be bought for what amounts to a royalty payment to the originator, but produced locally, either at home or at a local store like a Canadian Tire or Home Depot, rather than shipping it from, say, China to Ottawa.

  But 3D printing has even broader implications, notably in printing organic materials. It may be possible to print food directly from constituent compounds, leading to the development of food without farms. This has longer-term implications for food transportation, safety and nutrition that will – over time – affect public services.

  Of course, we don't know yet whether producing food without farms is financially attractive; it's too early to tell. And there is also the consumer acceptance issue: Will consumers buy food that is identical in almost all measurable ways to farm-grown food – or will such food be thought of as undesirable, like GMO grains?

  Ironically, printed foods may have unexpected allies: PETA, People for the Ethical Treatment of Animals, believes that meat produced in this way is ethically preferable to raising steers for slaughter.

- In the biosciences, we are now developing the ability to grow replacement organs, like hearts, lungs, kidneys, livers and so on, from a recipient's own stem cells. We are approaching also developing the knowledge that will gradually enable us to "turn off" cancers and some chronic diseases,

and lock out infectious diseases. Such developments will further extend life expectancies, with significant consequences for both individuals and society. These developments will be discussed in more detail later.

- Alternative energy sources combined with steadily improving energy storage (battery) technology will create significant challenges to traditional electric power generation and grids, and may destroy their economic feasibility.[62] Rooftop solar power, in particular, threatens to be a game changer, as the price per kilowatt of capacity is dropping at speeds approaching those of Moore's Law. In places, rooftop solar prices per kilowatt-hour are already lower than conventional electricity generation, even without including transmission or other costs.

  These changes threaten to disrupt the business plan of Ontario Power Generation within the next five years, before smoothly functioning alternatives are widely in place. This threatens to create power disruptions.

  OPG, as well as other electric power utilities, should take this developing trend seriously, and find ways to turn it to advantage. If they try to ignore it or block it, it could well destroy them as time and economics are on the side of the disruptive technologies.

So, it's clear that the potential gains in using alternatives to today's infrastructure systems will be remarkable.

However, cost is also a major issue for two reasons. First, new technologies always start out being expensive before they come down in price. This actually is solvable as long as planners are willing to wait for a technology to prove itself and to become affordable. There aren't usually a lot of prizes for being the first adopter of a new technology.

The second and more difficult cost problem is the cost of switching from the techniques we use now to the new techniques that are emerging. Hence, while autonomous vehicles may lead to massive cost savings over the long run, hefty up-front investments would be required to achieve those savings.

There will be other ripple effects relating to technology that I'll deal with later – notably its effects on labour markets.

Climate change and environmental degradation

The most important thing to remember about the coming effects of **climate change** is that Mother Nature always gets paid. Damage from extreme weather cannot be avoided, ignored, postponed or overridden by political opinions. Repairing the damage left by such events can be ignored or left to someone else, if the political will to do so is strong enough, but there still would be economic costs that would affect everyone.

Climatologists have been quite clear that no individual weather event can be traced specifically to climate change. However, the rising incidence of extreme weather events is directly traceable to climate change. This means that as the Earth's climate changes, regardless of why it is changing, we will experience a growing number of weather disasters, from flooding (as happened in Calgary and, to a lesser extent, Toronto in 2013), to drought (Western Canada in the summer of 2015), stronger hurricanes, thunderstorms, blizzards, ice storms and so on.

In other words, we cannot predict a once-a-century storm, but we can predict that once-a-century storms will now happen more frequently. Hence, we may have to plan on enduring such events once a decade, or even more often. This will require a much stronger – and more costly – response to weather and climate than in the past, and a more robust infrastructure to be prepared for such events.

In some ways, the worst part of this is that we don't know how changing climate will play out in terms of weather, so we don't know how to prepare. Will Ontario experience flooding or drought? Will our winters be warmer and snowier, or colder and drier? That uncertainty carries its own costs in planning terms.

For instance, suppose Ontario's "Tornado Alley," currently focused in southwestern Ontario, shifted eastward, and the GTHA were to start experiencing regular tornados. Would we be prepared? Current building codes do not contemplate frequent storms of such power. Imagine downtown Toronto, say at King and Bay, experiencing an F3 tornado,.

What we do know is that extreme weather events are becoming more frequent. It is therefore clear that we must consider this in any future infrastructure plans.

A more predictable future issue relates to **water supply**, partly because Ontario, like most other jurisdictions, has avoided necessary investments in maintaining and upgrading water-management systems, and because the availability of fresh, potable water is becoming a critical issue almost everywhere.[63]

Moreover, Canadians, Ontarians particularly, generally tend to feel we have all the water we need. Walkerton proved that this isn't necessarily the case, but there's more to the issue of water than just bad management, as this quote from Statistics Canada indicates:

> "In Ontario, the threat to water availability is high (more than 40 per cent) in the urbanized southwest part of the province. This is caused by large industrial and municipal water use and a low inland surface water supply. According to the OECD classification scheme then, this region was under water stress during these years (2005 and 2007). In other parts of the province, the results of the indicator calculations show a low threat to water availability."

Almost all of Ontario's population growth is in the southwestern parts of the province. Accordingly, Ontario cannot afford to be complacent about water.[64] Moreover, while this Statistics Canada study studied water usage during 2005 and 2007, the study uses a 30-year average of the water supply. Hence, this wasn't just a case of two years that happened to be unusually dry; this is a much broader problem related to the concentration of industry and population growth in Southern Ontario.

One of the simplest ways that municipalities can deal with potential water shortages is quite simple, relatively cost-effective and uses well-established, off-the-shelf technologies. It is to process sewage back into potable water, which would significantly reduce the need for additional fresh water. The problem is the so-called "yuck" factor.[65] Some communities in California have overcome this by pumping purified water back into aquifers, which also increases aquifer longevity. Or, to make this approach more palatable, municipalities can return the sewage, processed to drinking water quality, to streams, rivers or lakes for other downstream centres to use.

A more exotic future solution may be the use of nanotechnology water filters, such as those created using graphene – a highly organized form of carbon that is finding many applications. The potential to create a filtration system using graphene that is relatively cheap and effective on an industrial scale has not yet been proven, but is worth watching.[66] However, even if it proves to be successful, it leaves unanswered the other fundamental question (after cost) that bedevils desalinization efforts: What do you do with the toxic impurities that have been separated from salt or polluted water?

But however it's done, population growth, especially in southern Ontario, will require that water infrastructure be given a high priority.

Next **garbage**, or solid waste, will be a persistent problem until we face it squarely and stop trying to sweep it under the carpet. Efforts to divert solid waste from landfill to recycling are commendable, but won't be enough as we are running out of landfill sites.

The major problem with recycling is that it depends heavily on the market prices for the materials recycled. This will be particularly problematic in future as China, which has been the engine of demand for commodities of all kinds, will experience lower rates of economic growth in the future, which will lower the demand for, and hence the prices of, most commodities. In turn, this will make recycling less appealing economically.

Some parts of Europe have taken a different approach to recycling by legislating that the cost of a product should include the cost of recycling (or disposing of) the materials involved. Whether Ontario adopts that approach or not, we should be studying what other jurisdictions have done with garbage, adopt those techniques that are most cost-effective, **and then** take fullest account of the environmental consequences of use. The days of ignoring environmental consequences are ending, no matter how big the tantrums of those who want to continue to just dump.

Sweden has a somewhat controversial approach that is economically very successful. They first recycle as much material as they can, typically about 60 per cent of solid waste, and then incinerate the balance, generating power by doing so. They have been so successful in these efforts that they have run out of garbage and are now letting their neighbours pay them to take garbage for incineration.[67]

Many environmentalists in North America deplore this practice (and in the process seem to feel that they are holier than the Swedes, but on what seems to me to be thin evidence). They typically object on two principal grounds: first, that incineration produces dangerous pollution, and second, that it's a sin to destroy materials we may be able to reuse.

The first point can be refuted: "SEMASS, a waste-to-energy facility in Massachusetts, in the U.S., uses one million tonnes of municipal solid waste to generate 600 million kilowatt-hours of electricity every year and recycles 40,000 tonnes of metals. The annual toxic emission is less than half a gram."[68]

As for the second, I'd say let the burden of proof be on those who believe there's an economic way to deal with the roughly 40 per cent of solid waste that isn't currently being recycled. If they can demonstrate ways of doing so, then such techniques absolutely should be adopted. If not, then waste-to-energy incineration should be given serious consideration.

Fortunately, Ontario has a test case in its own backyard. The Durham Region York Energy Centre is just completing a waste-to-energy facility. This $286-million facility is projected to process as much as 140,000 tonnes of waste each year and generate approximately 17.5 MW of energy. As operations start up, the rest of the province will be able to witness, first hand, the feasibility of waste-to-energy as a means of dealing with the residue of solid waste after all possible recycling avenues have been exhausted.

The global economy

I want to touch on two aspects of the global economy that will affect infrastructure.

The first is that the **global economy is likely to grow much more slowly** over the next 20 years than the last 20 years. This is happening for a number of reasons.

First, China's population is aging very rapidly, and its workforce is actually in decline. This means that virtually all of its future growth will come from productivity growth. Admittedly, this still leaves them with a lot of growth potential, but it also means that their future growth is more likely to be in the range of 5-7 per cent than 8-12 per cent, and will gradually slow even further. The 2015 crash in Chinese stock market and the subsequent economic fallout could cause an even more rapid deceleration in economic growth.

Next, the other major sources of growth are experiencing significant teething problems. India has yet to show the will to cut through their thickets of red tape; until they do, their growth will remain modest rather than robust. Brazil is sliding back to its socialist ways and reverting to the habits of bad government. As a result, the country's growth is stalling. Rounding out the BRICs, Russia was never really a growth story, but rather a country that rode high while oil prices were high, but didn't diversify its economy. Add to this that the Russian population is in rapid decline and demographics argue strongly against solid economic growth.

There are other, emerging countries that will boost global growth, many of them in Africa, but they are not yet of a size or importance to matter as much as China and India on their own.

Next, this report turns to the importance of **education and its infrastructure** to Ontario's future.

The hollowing out of Ontario manufacturing due to globalization, which took place over the past 20-30 years, is largely done, but the fundamental lesson from globalization needs to be remembered: There is now one, world-wide marketplace; we are competing not only with each other and our American neighbours, but with everyone else in the world as well; the stakes are high, the competition is unforgiving and there is no going back.

The ultimate implication of that is that we need to have a globally superior education system, and education can no longer end when people cease to be young adults, but must carry on through our working lives. As well, our education system has to take account of the faster pace and the unforgiving demands of a global economy.

Ubiquitous access to the Internet has rendered the memorization of facts to be of minor importance, while the ability to perform wide-ranging research, absorb information quickly, ask critical questions, and be creative enough to produce innovative solutions to real-world problems are key. Yet, our primary and secondary schools continue to be hobbled by a "back to basics" mentality more suitable to the 19th century than the 21st. Meanwhile, roughly 75 per cent of budgets for public education are spent on salaries.

In an era when globally competitive organizations are lean and forced to be innovative, this antiquated model needs to be phased out. In particular, education should be customized to each individual student to enable them to approach their greatest potential.

With computers becoming far more capable, even intelligent, Ontario could be investing in technologies that allow human teachers to be more effective, working one-on-one with students when students have a problem, and allowing them to work in a self-directed fashion under computer supervision most of the rest of the time.

But no matter whether this is done in traditional ways, with teachers, desks and classrooms, or through technology, Ontario must move its schools to focus on creativity, critical thinking, and customized education rather than lecturing and memorization.

Meanwhile, post-secondary education is experiencing a revolution, with or without the permission of Ontario colleges and universities. Distance learning and online education are becoming commonplace, and the traditional role of the lecturer is under scrutiny. Why should a college employ local teaching assistants, for instance, to perform lectures when some of the best lecturers in the world can be available online, and when the students can view such lecturers on their own schedule rather than the lecturer's?

Tutoring would still be necessary, but even that can take place remotely. And the emergence of MOOCs (Massively Online Open Courses) and online degree and diploma programs indicates that the future of the traditional, ivy-covered campus is very much in question.

I would suggest that Ontario should be focusing on finding the best technological solutions being used anywhere in the world, asking each post-secondary institution to focus on what they are best at doing, and aiming to provide post-secondary education to a much broader audience than at present. Let me take these one at a time.

That technology is often, but not always, replacing traditional post-secondary models is clear and irrefutable. But we should learn from the eHealth fiasco: rather than re-inventing the wheel, we should find out who's doing the best work in this already well-travelled field and buy the technologies off the shelf.

Next, we should be prepared to offer not only traditional degree and diploma-granting programs, but also just-in-time learning for a wide-range of fields. In this way, Ontarians can upgrade their skills piecemeal and often without having to take time off work. Such learning may or may not lead to major credentials, like Masters or Doctorate degrees, but would encourage incremental learning, and credentialling that is focused on specific tasks for workers in the public, private and non-profit worlds.

And we shouldn't restrict such learning only to Ontarians. I believe we could make a sound financial case for selling Ontario education – from primary school through graduate studies – around the world. Indeed, I believe we might be able to make Ontario's education system self-financed. Even more important is that by so doing, our post-secondary institutions should be allowed to increase the resources they have available to pursue excellence.

What we should not be doing is building mausoleums to pander to the egos of rich donors in support of 19th-century education.

Human longevity and health management

According to Statistics Canada, life expectancy in Canada for men rose from 59 to 77 years in the 80 years from 1920 to 2000, while women did even better, going from 61 to 82 years. That means Canadians saw an increase in life expectancy of almost three months per calendar year, on average, through most of the 20th century.[69]

Much of this was due to advances in health care, particularly in childbirth. However, other, related advances were also helpful, such as the refrigeration of food and the identification of antibiotics.

The future holds even greater promise. Researchers now have a rapidly expanding understanding of human genetics, how diseases affect the body, and how environment and heredity interact to help, and harm, health. As a result, we can seek cures and treatments deliberately rather than by accident, or by trial-and-error.

Meanwhile, technology is making it possible to do things that people from earlier eras would not have believed possible. Replacement parts for human bodies are already being grown, from kidneys to heart valves, and the expectation is that the capability to replace every human organ through the use of an individual's own stem cells (with the possible exception of the brain) is on the horizon. Hence, if your heart wears out, or has incurred significant damage due to a heart attack, a new healthy heart will be grown from your own tissue to replace the old one.

Scientists are learning how killers like cancer or diabetes work, and finding ways of stopping them. They are starting to be able to design vaccines, antivirals or pharmaceuticals for a specific purpose, such as stopping or curing previously incurable diseases, such as SARS or Ebola. They may even be able to come up with a vaccine to prevent the common cold.

Wearable computers, with computer genies or avatars, will be able to monitor our health, heartbeat by heartbeat. We'll be able to significantly improve outcomes when a crisis develops, such as a heart attack or stroke, or when a disease, such as influenza, is developing. Indeed, precursors are already emerging in the marketplace that can perform some of these functions, from the Nike+ app that monitors your heart and running pace, to IntraXon's MUSE system, that monitors brain activity and provides feedback to help the user reach a calmer state of mind.[70] Systems like these, and many others, will continue to expand in scope to become wide-ranging health and well-being monitors.

As well, the exchange of data will supercharge medical research. Individual health information (stripped of personal identifiers) will be shared between each person's wearable computers, and regional, provincial, national and global health databases. This will provide a massive amount of searchable data that will enable computer intelligences and medical researchers to identify risk factors, genetic strengths, and help locate cures for existing and emerging diseases. (For more detail on this, see the FutureSearch blog post, "Health Care to the Year 2035."[71])

While all of this is wonderful news, it does have two implications for our health care infrastructure. First, people will be living longer, perhaps decades longer, than they have in the past. And second, this could add to the overburdening of the health care system. Accordingly, in planning the future of health management infrastructure in Ontario, it will be critical to identify the most cost-effective means of health management.

Cost-effective health management will be very different from traditional health care. The practice of medicine should make steadily increasing use of technologies, such as IBM's Watson computer intelligence, to assist health care providers in making faster, more accurate diagnoses, to map out an evidence-based health management regime for every Ontarian that needs it, and to do so using the least-expensive means possible.

This approach may lead to non-traditional approaches that raise the hackles of many groups involved in today's health care system. Looking at demographics, we will have fewer doctors and their services may be too precious for them to continue to act as the health system's gatekeepers. And it may be that hospitals should be avoided unless there is no other alternative that will serve. This is so because hospitals are enormously expensive, and because they serve as an inadvertent breeding ground for infection, especially antibiotic-resistant bacterial infections.

In place of these traditional entry points to the health care system, it may be that money should be invested in clinics that specialize in initial visits (i.e. gatekeepers), staffed by nurses or physician associates and supported by computer diagnostic systems; others that specialize, and create assembly lines, for in-demand procedures, like endoscopies, knee, hip or retina replacements, or the treatment of hernias. Such clinics would cut waiting times, improve outcomes by having procedures done by doctors who specialize in them, and relieve the pressure on the rest of the health system by dealing with the most demanded procedures.

In turn, this might mean that Ontario should no longer build or expand hospitals for treatment (as opposed to research) except in locations that are significantly underserved. What is clear is that we will not be able to afford the traditional answers that have grown up, organically, over the decades at a time when cost-effectiveness will be critical to the survival of taxpayer-funded health care system.

The widening tears in the fabric of society

The rise of homelessness and the growth in the penal system have important implications both for the social good, and for infrastructure planning.

What I will not address are the moral implications of these issues. There are people who believe that being homeless or being in jail is a sure sign that someone is a bad, unworthy person. Others believe it means such people are victims who must be helped. I don't wish to enter into that discussion.

Instead, my concern is whether we are properly allocating the infrastructure investments related to these issues, because both will become more expensive in the future.

In the case of homelessness, there is a very real risk that an increasingly difficult and unrewarding job market will throw a steadily rising number of people onto the streets to become homeless.

In the case of the penal system, there are two issues. The first is that in a difficult employment environment, having a prison term on your résumé will almost certainly kill your job prospects. In effect, when someone is imprisoned, they become almost automatically unemployable for the rest of their lives. The second problem with the penal system is that aging prisoners require a steadily increasing amount of health care, making their upkeep more and more expensive.

Neither homelessness nor the penal system are of interest to the general public, but the costs to society of sweeping the problems under the rug are probably high enough to justify a radical revamping of both. Yet, part of the problem is that our reactions to these two issues are so close to being knee-jerk that we don't even collect much data on the costs.

On the subject of **homelessness**, two American jurisdictions did collect data, and also tried an apparently radical solution: giving homes to the homeless with few, if any, strings attached. One was liberal New York City; the other conservative Utah. The result?

> "Between shelters, jail stays, ambulances and hospital visits, caring for one homeless person typically costs the government $20,000 a year. Providing one homeless person with permanent housing, however – as well as a social worker to help them transition into mainstream society – costs the state $8,000."[72]

But there's a real barrier to this kind of reform, which is public opinion. Most people are opposed to giving homeless people something for nothing, especially if it encourages others to take advantage of the system. We fail to realize that we are implicitly paying what might be called a "homeless tax" by not giving shelter to the homeless.

A better solution might be to find a way to have the recipient of such housing contribute something in return. They could be offered the opportunity to buy their home through an instalment plan or earn their home by helping build additional housing.

Ironically, this may actually be harder and more expensive to police, but the politics of something-for-nothing may require it.

There is much more documentation relating to the costs of the **penal system**, more so in the U.S. than in Canada. In fact, even neo-conservative Republicans, such as the arch-conservative Koch brothers, in the United States have flipped positions, and are now advocating a revamping of the

entire legal system, particularly jail sentencing, because the results are so costly and the system is so ineffective.[73] No thinking person still advocates that getting tough on crime is an effective answer.

To pick a particularly stark example of the direct costs of the penal system, New York City's Independent Budget Office found that "in 2012, it cost the city $167,731 to hold each of its daily average of 12,287 inmates, or about $460 per inmate per day. Undergraduate tuition at Harvard University is $38,891 annually, or $155,564 for a four-year degree."

In other words, it would be cheaper to send a NYC inmate to Harvard for four years than to lock them up for one year .[74] This is, admittedly, an extreme example. In 2010, for example, the average annual cost of imprisoning an inmate in a U.S. federal prison was US$28,284. In California in 2009, the cost of keeping someone in a state prison was US$47,102.[75]

In Canada, the costs are comparable. A 2012 report from Corrections Canada indicates that it costs an average of C$113,974 to keep an inmate in a Canadian federal prison.[76]

Are there alternatives? Yes there are, and technology will increase the range and subtlety of these alternatives as smart computers and wearable computers will be able to monitor the locations and behaviour of people convicted of non-violent crimes with increasing sophistication and precision. But we don't have to wait for technology to bail us out.

The Don Drummond report, commissioned by the province of Ontario, indicated that it costs $183 a day (which projects to $66,795 a year) to keep someone accused of a crime in jail, compared to $5 a day ($1,825 a year) to keep them on supervised release.

It's clear that Ontario should learn from America's mistakes, and stop looking at incarceration as the only solution for people accused, or convicted, of committing a crime. In fact, a recent *Globe and Mail* editorial noted that more than half – 55 per cent – of people held in provincial and territorial

jails have not been convicted, but are awaiting trial. The editorial concluded that "The system is broken."[76]

Paying attention to the megatrends relating to these two aspects of society clearly requires fresh, open-minded thinking – and a clear fix on finding better uses of infrastructure spending than on traditional facilities to cope with homelessness and crime. One alternative is to use funds otherwise allocated to traditional infrastructure and government programs to results-focused innovative financing, like Social Impact Bonds, Green Bonds, "Pay for Success" Bonds, and in the case of First Nations, Community Benefit Agreements or "Impact and Benefit Agreements."

The rapidly eroding job market

It is much harder for someone to get a job today than it was 50 years ago, even 20. This is largely due to two factors that have drastically reshaped the job market: one well known and documented, the other widely acknowledged, but largely overlooked. The first is foreign competition, and the second is domestic automation.

Foreign competition has hollowed out employment in Ontario's economy, notably in the manufacturing sector, as Rapidly Developing Countries (RDCs) grew with the emergence of the global economy. In particular, China and India drew tens of millions of jobs away from more expensive, developed countries, including Canada. The result is that it is no longer possible for someone who has no desire to go to college or university to have a friend or family member speak to the foreman at the local factory, and get a job on the line. That just doesn't happen anymore, although it was commonplace in the 1960s and before.

Foreign competition is not going away any time soon. China may no longer be as big a draw for manufacturers as it was, but manufacturing jobs will follow low wages to new places around the world. They are unlikely to return to Ontario because it costs too much to live in an expensive, developed country like Canada.

Meanwhile, even this trend is being disrupted by the other factor at work: **automation**. As computers continue to get cheaper, faster and more sophisticated at greater-than-exponential speeds, the work that they can do faster, more effectively and more cheaply than humans expands at ever-accelerating rates as well. This has been discussed, but its importance has been largely overlooked. And it's no longer just blue-collar jobs that are being replaced by machines. For instance, law and accounting jobs are rapidly being replaced by sophisticated computer systems. Indeed, any job, at any level, that involves routine, doing the same kinds of things repeatedly, is very much at risk to being replaced by computers, robots and automation.

Although this doesn't directly relate to any specific infrastructure system, it does affect all of them. If these trends continue – and I see nothing that can stop either of them, short of massive global disasters of some kind – then our governments and our society will need to take a completely different approach to the employment markets.

If we do not change how we educate and equip people for employment, then our governments will see their tax base erode, the divide between the haves and have-nots will expand, economic growth will be stunted by lack of consumer demand and, based on what has happened elsewhere, we will see a rise in social unrest. And, as an important side effect, this will undercut the investment funds required for infrastructure investments.

What can we do about this? First we need to move our education system from the 19th century to the 21st, including encouraging grownups to return for additional educational top-ups on a just-in-time, as-needed basis. As well, students in secondary school and higher should be tutored in practical job-seeking skills.

Then we need to be more proactive about helping people find – or create – jobs. At the moment, most job seekers are pretty much on their own, with occasional, inconsistent government help. This needs to become more systematic, and more robust to cope with the labour markets of tomorrow.

And such systems should provide access to additional training to allow workers to upgrade the skills they need to find work.

And helping job seekers create their own jobs as entrepreneurs will also be necessary as people increasingly will be responsible for their own careers, whether they sign their own paycheques or someone else does. This includes providing course materials in the Ontario education system on how to create and run a business, plus systems in the economy to help people start and sustain businesses. Hence, low-cost services that help with accounting, payroll, taxes, plus providing mentors for entrepreneurs, much as CIDA does abroad, would all be valuable. The government doesn't necessarily need to run such programs, merely make sure that they are available.

Governments should seek to work with private sector employers to accomplish these things, rather than try to do it all on their own. And they should remind employers that if consumers aren't earning any money, they are unlikely to buy many products. This was something that Henry Ford knew quite well, but which corporate chieftains seem to have forgotten.

Conclusions

In preparing this report, I came to three primary conclusions about the future of infrastructure investments in Ontario:

1. We will have to address the massive underinvestment of the past several decades, as well as prepare for the growing needs of Ontario's future. If we do otherwise, the costs to society will be higher than the costs of investment. We will pay either way, but we will be better off if we make the investments needed.

   There are always people who will take a populist stand, arguing against raising taxes for any purpose. They are either ignorant of the costs of inadequate infrastructure or deliberately advocating something they know to be harmful in order to gain a selfish, political advantage.

Some argue that governments cannot be trusted to use tax funds effectively. This is a reasonable argument and, with the scarcity of funds that I expect we will experience in future, it is vital that we make good use of any funds earmarked for infrastructure. Finding ways of making sure results are measurable and transparent, and that those responsible are accountable, is entirely appropriate. Refusing to allocate money for infrastructure investment is simplistic, selfish and, ultimately, self-defeating.

2. We will be stretched to find the money to make the investments that we must make. In particular, demographics, notably the aging of the Boomers and the cost of their health care needs, threatens the financial solvency of our government-sponsored health care system. Climate change will make us spend money in places we don't wish to. The global economy will force us to be lean and effective, giving us no cushion for bad planning or careless investing. And the rapidly mutating job market threatens the underpinnings of our economy, as well as the very fabric of our society.

   We will have to plan carefully, allocate funds on the basis of real, measurable needs as opposed to political expediency, and use means of ensuring that the taxpayer is not left on the hook for sloppy implementation or unreasonable cost overruns.

3. The infrastructure systems that we have used in the past may be too expensive to use in the future. Accordingly, we must seek new solutions to infrastructure needs when such solutions can be shown to be more cost-effective. In particular, we need to look at new possibilities being brought forth by ever-accelerating technologies for ways to do things more effectively, and with less money.

The raw necessity of investing heavily in infrastructure should drive us to find better ways of doing things in a time when resources will be scarce. In a very real sense, we will invent our future. We should work hard at doing it well.

APPENDIX B

Practical Ways to Think About Ontario's Current and Future Infrastructure

Infrastructure is made up of the physical plant and distribution systems that make economic activity possible. It ensures that capital and labour can be applied in a way that produces wealth and supplies markets. It is an essential ingredient in economic growth and prosperity and it is one of the key contributors to productivity. A lack of good infrastructure can also diminish productive capacity and the efficiency of markets for goods and services, resulting in higher costs and diminished price competitiveness.

But the term "infrastructure" covers a variety of systems and networks. These are governed by differing physical characteristics, different use and ownership patterns and differing periods of longevity. Moreover, in the future, our conventional understanding of infrastructure will also change in ways not seen since the advent of steam, the electricity grid and the automobile.

Different types of infrastructure also have different relationships to the society and economy that they serve. Some infrastructure is used to transport goods and services, to or from centres of production or economic activity. Other infrastructure is used to deliver people and business-support services to centres of employment or training. Some infrastructure is used to support a community's quality of life, by underpinning safe, healthy, sustainable living conditions for individuals and business operations.

In the RCCAO's publication "Investing in Ontario's Infrastructure," public investment in infrastructure is defined as: "… including roads and highways, rapid transit, water supply and wastewater treatment, rail, aviation, water transportation, as well as electricity and broadband infrastructure …"[78]

A more detailed summary of infrastructure might look like this:

A. Transportation infrastructure

1 Road transportation and transit infrastructure

Road transportation, including arterial roads, expressways, tunnels and bridges. This category would include toll roads and privileged use roadways (bus lanes, HOV lanes, toll lanes, etc.) and congestion tolling. It supports passenger vehicles, transport vehicles, fare-charging scheduled-service commercial passenger buses, school buses and chartered bus transportation.

Related to road transportation are scheduled public transit services using roadways and rails, as well as commercial bus services and taxi or airport vehicle services. It includes rail-based municipal transit vehicles (trams or streetcars), surface or sub-surface trains and trams on their own right-of-way. In the future, this would increasingly extend beyond current access and control systems (stations, switching systems, electronic fare cards, etc.) to platform-side door systems, automatic trains, automatic train-control systems, credit-card-based fare regimes, etc. Public transit services include commuter-rail services operated by both public (municipal, GO Transit) and private authorities (VIA Rail Canada).

Finally, road transportation includes the facilities and services that support **truck transport** and logistics, including border-clearance infrastructure and intermodal facilities serving some combination of air, water and land transport interface.

In the future, this category of infrastructure will increasingly include intelligent transportation systems (automated vehicle control and driver-assisted vehicles, road pricing, expressway system-access controls, in-vehicle technology for distance-separation and collision-avoidance, etc.) and computer-aided logistics and dispatch, from supply chain to new formats for ride- or vehicle-sharing or load-sharing commercial transport. Continuing urbanization in Ontario and the growth of its major urban centres will require much broader and more integrated regional transit and transportation planning than has been the case in the past.

2 Rail transportation infrastructure

In addition to the above-noted local public transit and regional commuter rail transport infrastructure, rail transport primarily includes the rail beds, tracks, land corridors and switching systems that make possible rail freight transport and inter-city passenger rail transportation, along with the capital rolling stock of locomotives, freight cars and passenger carriages. This category includes "rail interface" infrastructure, such as grade separations and other types of bridges and tunnels, intermodal transport hubs and logistics marshalling yards.

Among the most significant pieces of rail transportation infrastructure is real estate, including linear rights-of-way and marshalling yards, as well as major terminals, such as Union Station and rapid-transit interchange points, like major Toronto subway stations. In the future, this infrastructure may be supplemented by the need to support high-speed interurban passenger rail services, if the level of ridership and population can sustain it. As well, rail has become a major means of transporting commodities, such as heavy oil and dangerous chemicals, needed by society and the economy, but whose transport brings risks, especially in densely populated areas.

3 Aeronautical infrastructure

The network of major and minor airports and landing strips makes up the majority of this category, including the air-traffic control infrastructure. One of the largest private investments in aeronautical infrastructure – indeed one of the GTA's largest single infrastructure projects – was the building of Terminal 1 at Pearson by the "privatized" Greater Toronto Airports Authority in the early 1990s. Also to be included under the heading of aeronautical infrastructure is the health care-related aircraft and heli-pad system for trauma response and critical patient transport, serving trauma centres and other hospitals. In future, aeronautical infrastructure will be supplemented to manage drones and other unmanned craft, for use in consumer and commercial applications. As well, the steady compounding of global air traffic will necessitate investment in new, more flexible air-traffic control systems.

4 Water transport infrastructure

Canals, locks and other inland waterways, ferry services, small craft harbours, port facilities and port-access infrastructure, such as intermodal terminals and customs clearance, would be included in this category. The facilities of ports and harbours variously serve the needs of industry, agriculture, pleasure craft, construction (aggregates, stone, lumber, steel, asphalt, etc.) and municipalities (primarily road salt). There is also mixed-use public infrastructure, such as marinas and waterfront developments. The single largest pieces of Ontario infrastructure in this category are the freight ports, canals and locks that comprise the St. Lawrence Seaway system.

B. Energy and telecommunications infrastructure

5 Energy infrastructure

Across North America, energy infrastructure embraces the generation or sourcing, regional transmission and local distribution of energy. Most commonly, "energy" includes natural gas, electricity, petroleum fuels and steam. Electricity's sources include nuclear energy, renewable-source energy (solar, wind, geo-thermal), burning of fossil fuels (coal, oil, diesel, propane, natural gas, etc.) and hydro-electrical (from turbines fed by dams, tides and waterfalls).

In the future, energy infrastructure will need to be extended, in order to improve the electricity grid, to overcome transmission capacity bottlenecks, and to exploit generation business opportunities. On a "macro" scale, this might include linking Bruce Power's surplus nuclear power supply and storage capacity with U.S. markets, as well as improving linkages between Ontario markets and electricity supply from Hydro Québec. On a more localized basis, it will also include overcoming regional bottlenecks, such as transmission to the Toronto and region market from generators east of the city, and linking northwestern Ontario supply with markets east of Lake Superior.

In the future, the patterns of electric power use and production will change, requiring changes in the infrastructure for power production and distribution.

The burgeoning of electronics and wireless technology will add to electricity demand. The widespread use of the electric car and the expansion of electricity-based urban and regional rail transit will also make it necessary to increase electricity supply. It will also cause the private sector to build a network of retail fuel suppliers to parallel gasoline and diesel fuel retailers.

The emergence of widespread and increasingly competitive rooftop solar power panels, coupled with local electric power storage systems, such as the Tesla Powerwall, are going to radically and unfavourably change the economics of electric power utilities. Some suggest that next-generation solar generation may radically alter the economic value of conventional power-generating capacity. Only the lowest cost generators may survive. The risks are real, especially given the scale of investment required. If they come to pass, such changes would require a major rethinking of Ontario's power infrastructure. Indeed, it may be that the power transmission grid will become more valuable than Ontario's power-generating capacity.

Energy infrastructure will need to be extended in places, in order to improve the electricity grid, to overcome transmission capacity bottlenecks, and to exploit business opportunities for power generation. It will also give rise to

a wave of localized micro-generation, from increasingly inexpensive rooftop solar generators to district heating and cooling systems.

If the damaging impacts of coal-fired electricity generation come to be accepted by mid-western and northeastern U.S. states, business opportunities will increase for major Canadian surplus clean energy electricity generators, like Bruce Power, OPG and Hydro Québec.

6 Telecommunications and electronic infrastructure

Telecommunications infrastructure includes fibre-optic cable and wired telephony, switching equipment, microwave towers and receivers. (For example, the $170-million initiative of the Eastern Ontario Wardens' Caucus to provide broadband connectivity for all of rural and small town Eastern Ontario is one of the trendsetting public-private partnerships in Ontario.) Electronic infrastructure similarly includes systems for broadcast and reception of wireless communications, as well as server-farms and data warehouses and air transport communications. An important sub-category in this field is the electronic and diagnostic infrastructure serving the health care field (diagnostic imaging equipment, diagnostic imaging and related file transfer, robotic evaluation and surgical treatment applications, electronic communications with remote clinics, etc.).[79]

In the future, this infrastructure will likely be supplemented by expanded use of closed-circuit television systems, and security infrastructure related to monitoring and interception of telecommunications and radio-frequency identification (RFID) electronic signals for a wide variety of personal, household, business and public security uses. Mobile communications are exploding, as is the demand for the latest, fastest high-speed Internet. Much of the infrastructure for this is created by private sector suppliers (Bell, Rogers, Telus, Xplornet in rural areas, etc.), but given the importance of such infrastructure for our economic future, governments and consumers may well ask: "Are we being adequately served by regulated oligopolies?" In places like Singapore and South Korea, the value of public investment in telecommunication and electronic infrastructure is evident. Are we being left behind?

C. Environmental infrastructure

7 Water infrastructure

Water infrastructure includes the treatment and distribution of potable water, the collection and treatment of sanitary sewage or wastewater, and the management of stormwater run-off and drainage. The infrastructure for stormwater management also includes extensive flood-prevention real estate assets held by flood-management agencies (like Ontario's conservation authorities), municipalities and private landowners. In some jurisdictions, like the U.K., responsibility for water utilities and flood management, are often combined in a single authority, typically operating across a watershed. Globally, utilities like wastewater systems are often organized on a regional basis, and owned or operated under contract by the private sector. In northwestern Alberta, the municipally owned utility Aquatera provides a range of these environmental services to a number of municipal clients. Fiscal, investment and efficiency considerations may generate similar evolution in municipal functions, such as wastewater and/or stormwater management.

The facilities to treat, distribute and collect water also have a close connection to energy infrastructure, as they are substantial consumers of energy.

- In the future, extreme weather events and other climate-change provisions may expand the scope of infrastructure related to mitigation and rapid recovery from wind, rain and ice storms, flooding and sewer backups (both sewage and stormwater). We will also see proposals and mounting pressure to transport some of Canada's abundant (and often shared) freshwater resources to the drought-parched areas of the U.S., including drawing-down water on shared waterways, like the Great Lakes, the Red River basin and the Columbia River system, or freshwater swapping with the Hudson Bay lowlands watershed.

Climate change threatens to change precipitation patterns, and may reduce the ready availability of fresh water supplies in various locations around Ontario. Other factors also impinge: society's tendency for chronic under-

investment in supply due to the out-of-sight, out-of-mind nature of potable water systems and the abuse of low-cost, conveniently available water supplies. Despite our superficially favoured position on the freshwater Great Lakes, we could see water shortages, similar to those already afflicting the western United States and Australia.

Shifting weather patterns may also require changing building standards and construction materials. A warming climate could bring to Ontario the so-called Tornado Alley of the U.S. Mid-West. Current building standards do not contemplate regular, violent storms and flash floods. But our next-generation infrastructure may need to anticipate it.

8 Solid and hazardous waste collection, recycling and disposal

The infrastructure needed to deal with society's waste is complex and often neglected. In most jurisdictions, solid waste management is the responsibility of local government, subject to regulations imposed by provincial governments for waste handling and disposal, and federal regulation of matters such as packaging and importation of foreign materials that will subsequently be disposed of in Canada.

In many municipalities, the responsibility for dealing with solid waste collection and disposal is assumed by the municipality or its contractor for most residential waste and often for the solid waste products of small businesses and small multi-unit residential buildings. The responsibility for industrial and commercial waste, including waste from large, multi-residential buildings, often falls to the owners of those enterprises, notwithstanding the fact that they pay municipal taxes that support the rest of the local waste-management system.

In addition to general waste collection, virtually all urban municipalities and most rural municipalities maintain a program of residential waste recycling (blue box collection and recovery of commercially marketable materials) and parallel programs for the collection and disposal of hazardous waste, the policing of sewer discharges, and the regulation of dumping of construction

materials and soil. The government of Ontario also regulates these processes, with particular attention to solid waste disposal facilities and sites, protection of source waters from contamination by waste and so on. The government of Canada regulates wastes associated with the production of nuclear energy.

Ontario communities have long resisted expansion of landfill sites for solid waste disposal and, in particular, energy-from-waste incineration plants. Ambitious programs to promote waste recycling and resource recovery have helped to mitigate the impact of this reluctance to accommodate regional waste disposal, but costs are high and markets for most of these products are soft, especially with the decline of the newsprint industry.

In the future, when commodity prices for aluminum, steel and precious metals justify it, existing and closed landfill sites may afford opportunities for recovery of metals, as well as established technologies for recovery of methane gases for energy generation. Energy from waste facilities are increasingly using advanced technologies to mitigate real and perceived environmental and health problems with these facilities.

D. Social and health infrastructure

9 Social infrastructure, and social and health policy

Not referenced in the initial definition above is the suite of investments made largely by the public sector in health care, education, law-enforcement and critical response (prisons, courts, police facilities, emergency medical response, fire suppression, etc.) and affordable and supportive housing (public and social housing, long-term care homes, etc.). A number of cultural, sporting, heritage and recreational facilities would also be included in this category, including legacy facilities from events like the Pan Am games. These infrastructure investments are large, continuing and have a significant claim on the funds available for investment in public and non-profit infrastructure. To this list might also be added the facilities that serve government, including city administration buildings, public works facilities, government office buildings, archives and so on.

(The potential future implications of megatrends on health care and education are covered extensively elsewhere in this report.)

Not often considered is the infrastructure to support public policy objectives, such as designing and retrofitting public and private facilities for physical and perceptual accessibility, energy efficiency, systems sustainability (water, building materials, solid waste), emergency evacuation and public safety, and so on.

Building shells and paved surfaces that respond to environmental considerations, like smog or rainwater preservation, will become more common and may be required by building codes.

In the future, building techniques and building materials will be asked to address a range of needs, beyond current LEED standards of sustainable accommodation and energy conservation. Building shells and paved surfaces that respond to environmental considerations, like smog or rainwater preservation, will become more common and may be required by building codes.

The rapid population growth among indigenous people in Canada will have an impact on the demand for infrastructure investment in First Nations communities and other communities with a significant Aboriginal population. The widened scope of Aboriginal rights in connection with traditional lands will make public infrastructure subject to new conditions and timing. It will also be reflected in community benefit agreements to compensate for resource exploitation, which frequently include community infrastructure provisions, including training and/or employing Aboriginal workers or companies to work on infrastructure projects. These investments will initially focus on communities in remote locations, with better energy, road and telecommunications infrastructure. With increasing out-migration from First Nations reserves and growing urban Aboriginal populations, the future may also see relocating and rebuilding existing remote First Nations communities to more environmentally and economically sustainable locations, reminiscent of Newfoundland's Outports Relocation program.

E. Government business enterprises (GBEs); and Ontario's and Canada's public assets portfolio – tangible and intangible

There is a long list of public assets in the hands of the Ontario government and its agencies, and in the portfolios of local governments and local public authorities. Their asset value is also very large, although deteriorating due to lack of timely reinvestment and deferred maintenance. They cut across the various main categories of civil infrastructure, or they may be considered a class of infrastructure on their own, like the LCBO chain of stores or the OLG casino network. Many public assets can be found on the balance sheets of governments and other public authorities; others, such as so-called "intangible" assets, like databases, the value of government monopolies or good will, may be ignored in financial statements. Finally, many public assets are reported based on depreciated acquisition value ("book value"), rather than their "mark-to-market" value in the hands of others or in the marketplace or allowing for current borrowing rates.

10 Government business enterprises (GBEs)

Within each of the foregoing categories, as well as in areas not normally considered infrastructure, are the "businesses" of government, more commonly referred to as "government business enterprises" (GBEs). The way in which infrastructure assets are held may create an additional asset, in the form of the corporation or entity that owns, operates and manages a facility or network. Among the GBEs most commonly recognized are the LCBO, Hydro One, Ontario Power Generation (OPG), Ontario Lottery and Gaming Corporation (OLG), Ontario Place and Ontario Northland Transportation. In any discussion of financing new infrastructure, or refurbishing or expanding existing infrastructure, consideration should be given to the role that could be played by leveraging existing assets, including government business enterprises and their infrastructure. This would include full or partial sale, leasing, concessions, joint ventures, securitization of cash flows, dividends, mortgaging, collateral security for debt, and other tools to "leverage" our public infrastructure assets.

Hydro One and its counterparts: With changes in electricity generation, transmission and distribution, what is the new business model of traditional major players, like Hydro One?

11 Ontario's public assets portfolio

Traditionally in Ontario (and in Canada generally), public and community assets have largely been acquired, operated and maintained by public authorities and with public finances.

These public assets include, among others:

- Transportation (roads, public transit, Ontario Northland, regional and local airports);
- Public utilities (e.g., potable water and wastewater systems; solid waste collection, recycling and disposal; and, Hydro One, OPG and vestiges of local electricity distribution [municipal hydro commissions]);
- Hospitals and public health care facilities;
- Schools and post-secondary educational institutions;
- Parks, recreational, gaming and sports facilities, including stadiums and arenas;
- Stormwater management systems and associated land holdings, including conservation authorities;
- Heritage, library and cultural institutions, including public theatres and museums;
- Emergency medical and firefighting facilities, equipment and services;
- Policing and justice facilities, services and equipment, as well as correctional facilities; and,
- Social housing and long-term care homes.

When preparing an inventory of public assets at the provincial level and on a smaller scale at the local and regional level, one needs to add "government business enterprises" and property holdings. The LCBO, OLG, OPG, Hydro One, the land holdings and buildings managed by Infrastructure Ontario, MNRF, MTO and Waterfront Toronto are a few examples of these valuable public assets held in public hands.

Schools: How should we manage the portfolio of Ontario elementary and secondary school buildings in the face of: (a) projected declines in student populations; (b) the continuing shift of populations from rural areas to urban areas; and (c) the rapid growth of the suburban and exurban areas of Ontario's major urban centres, especially in the GTHA?

Prisons: America's 40-year experiment with high levels of incarceration has demonstrated quite clearly that prisons are neither cost-effective, nor socially effective. Public policy will increasingly examine the cost benefits of alternatives for effective law enforcement and peace keeping. The answers will have significant implications for infrastructure intensive public services, like prisons, courts and police services, as they are put through an unfamiliar return-on-investment or pay-for-performance test.

Public housing: Just as prisons are proving not to be cost-effective, homelessness and lack of housing affordability imposes disproportionate demands on the public purse in policing, health care, sanitation and welfare rolls, as well as creating social divisions and dissatisfaction. The costs and potential ROR of investments in public housing, as well as other means of reducing the public burdens of homelessness and poor housing affordability, will drive new, more innovative solutions to housing, including physical infrastructure ideas like those being proposed by the leadership and membership of the RCCAO.

There are a few exceptions to this Ontario and Canadian tradition of funding community, utility and "economic infrastructure" assets through government action. Examples would include Canada's rail infrastructure, the transmission and retail disposition of natural gas, telecommunications, privately owned cultural enterprises (e.g., Mirvish theatres) and, in recent years, privately operated electricity generation, transmission and retail distribution.

Although these examples demonstrate that not all socially and economically beneficial assets must necessarily be in government hands and financed by government, they remain the exceptions. In Canada, the vast majority of public assets are within the public domain for their (tendered) construction, operation/staffing, maintenance/refurbishment, expansion and, most particularly, for their funding and financing.

A Comment from Grush Niles

Comment on "Future of Infrastructure" report

This report makes a key point at the outset: there is too little understanding of the need to build the right infrastructure and the need to build infrastructure right for the long term.

With this in mind, we'd like to focus purely on the issue of road, highway and transit infrastructure. The GTHA's well-documented deficits in transit, road maintenance, bike lanes and tolled highway lanes are not unique. For decades, large cities throughout the world have been up against the wall of urban growth, congestion, rising costs and environmental degradation.

Many thoughtful observers believe the developed world is on the cusp of a tsunami of automotive innovation that could hopefully enable miraculous relief from today's typical circumstances, but could just as likely cause a terrible exacerbation. Furthermore, planning for the next 20 years with an expectation of impending vehicle robotics is wholly unlike any other 20-year planning exercise we might have engaged in over the past decade.

Because the robotization of transportation vehicles is both certain and uncertain, infrastructure planning has been put at a new kind of disadvantage. Specifically, we can be quite certain of someday needing no human operator for nearly all vehicles in almost all circumstances – i.e., pervasive vehicle autonomy. Many of us can guess things about the nature of some of the disruption that will accompany this technology. But for most of the robotic future there is only uncertainty.

Collectively, we read many contradictory predictions about robotics vehicles. These are often biased: a manufacturer's spokesperson wanting to position their firm's products; a professor of transportation engineering simulating or extrapolating hopeful solutions to an enormous set of problems; a safety engineer wanting to advance the life-and-death value of this technology as soon as possible; journalists awed by what they see at a trade show.

Predicting vs. Hoping

All of this taken together leaves those charged with deliberating a path for a regional municipal transportation plan with many difficult questions.

How quickly will the autonomous vehicle arrive? Nobody can ascertain the speed or time of arrival of full autonomy – i.e., full pervasiveness in a region or city. We can easily imagine technical feasibility in most operating circumstances, but we cannot say when sufficient reliability will be exhibited in every circumstance—indeed, some credible analysts express doubts about this. That means we don't know when (or if) any different sorts or scales of infrastructure will be needed, or how long what we contemplate building in the interim will be needed.

Will robotics mean more or fewer vehicle kilometres travelled? Currently, humans are capped out at a worldwide average of about one travel-hour per day. If we can eat, play, sleep, read, work and shop instead of attending to driving, how much further will we choose to sprawl? Recent evidence appears equivocal. Many people who cannot drive now forego trips or have chauffeurs or use transit unwillingly. Will non-drivers with new freedom of mobility add to kilometres travelled? Or increase the number of cars owned?

Will robotics make travel cheaper? Humans now spend an average of 11 per cent of their disposable income on travel. Robotics will lower the cost of the vehicle, its fuel, its insurance and its parking fees. When something is cheaper, more is consumed. Will the travel savings be spent on longer trips? Or on bigger vehicles as is common in North America now? One might think rational travellers would spend the windfall travel budget on something else, but that is true of only some people.

Will new automotive players change the landscape of solutions? Will incumbent automotive manufacturers stage innovations to sell more semi-robotic vehicles and very appealing safety features for more model years, or will new apps-on-wheels players like Google, Apple and Uber steal the puck? Both types of players want to sell more. The new players sell kilometres. The incumbents sell vehicles. And some of those incumbents are already thinking about selling kilometres, too. Either way, there would be more vehicle kilometres travelled.

In what solution order will robotic vehicle technologies be applied? Will we robotize transit or goods logistics first? Expecting both to happen all at once – say over a decade – may be physically, operationally and socially impractical. Or will governments set regulations and let automotive manufacturers sell what they might to household consumers, while letting the insurance companies work out the issues of mixed traffic – driver-in and driver-out – sharing our roads.

Will shared fleets or household vehicles dominate? Critically, the jury is out on the matter of vehicle ownership, even though hope-filled forecasts by some paint a picture of inevitable, widespread vehicle sharing. Will most autonomous vehicles be owned as family vehicles are now? Or will the advantages of shared fleets be available to, evident to, and selected by the great majority of travellers so that household vehicle populations shrink dramatically? Will the car become more of a travel service and less of an accessory – i.e., all about the trip, nothing about status? Many academics are on record as saying "few people will own autonomous vehicles; most will share them," but there are many reasons – rational or otherwise – that most people currently prefer ownership, even while a growing few have found ways to avoid owning a vehicle. The backdrop of culture, habit, status, privacy and convenience of owning can be stacked against the rational economic notions of sharing and be used very effectively by automotive marketers. That has already started. Will irrational consumption or rational conservation win out? It's impossible to know which future will prevail, and we face many debates.

Some simulation-based research has been generated for cities such as Austin, Lisbon, Manhattan, Stockholm and others. Consistently, the researchers find that each simulated autonomous vehicle can replace about 10 current family-owned vehicles. The simulations are realistic in that they have been parameterized using the origin-destination (O-D) data collected in those cities but, in most cases, the researchers imply or reviewers conclude that such figures can be extrapolated to the world vehicle population. In *The End of Doom*, Ronald Bailey writes:

> Researchers at the University of Texas, devising a realistic simulation of vehicle use in [Austin] that took into account issues like congestion and rush-hour usage, found that each shared autonomous vehicle could replace 11 conventional vehicles. Notionally then, it would take only about 800 million vehicles to supply all the transportation services for nine billion people. That figure is 200 million vehicles fewer than the current world fleet of one billion automobiles.

> In the Texas simulations, riders waited an average of 18 seconds for a driverless vehicle to show up, and each vehicle served 31 to 41 travellers per day. Less than half of one per cent of travellers waited more than five minutes for a vehicle. In addition, shared autonomous vehicles would also cut an individual's average cost of travel by as much as 75 per cent in comparison to conventional driver-owned vehicles. This could actually lead to the contraction of the world's vehicle fleet as more people forgo the costs and hassles of ownership.

There are several problems with these simulations and the conclusions drawn from them. Research underway at Grush Niles Associates concludes that these simulations, constrained by the availability of useable O-D data, are unwarranted generalizations that cannot be reasonably extrapolated to suburbs and rural areas or work/service-related vehicles. Extrapolations such as echoed by Bailey must assume an inevitable and general willingness of all or most travellers to use shared vehicles. While there is much good to be said for a sharing economy, there is no evidence that all or most humans will engage this way. In fact, we can show dozens of barriers to such a general outcome. We can also derive ways to overcome these barriers to some degree, as will be described below.

How can we turn such a large ship?

In spite of a plethora of unknowns – or perhaps because of that – Ontario and its municipalities can start now to develop policy direction that is more likely to make a desirable outcome prevail than just hoping.

By waiting, municipalities risk the consequences of being swept up by exponential innovation that government will find hard to track, regulate and manage. If Uber caused regulators headaches in 2015, the disruption wrought by robotics by 2035 will be a thousand times worse. The 20-year future that starts now is harder to predict than any prior 20-year future.

We know we cannot *build* our way out of congestion by simply building larger versions of what we have built until now. And we know what we have now is inadequate to today's task. Without an ability to accurately predict the nature of motorized surface transportation vehicles in 2025, 2035 or 2045, we now cannot even *design* our way out of congestion.

The only way to escape this conundrum is to *innovate and integrate* in order to find a better way through. We need to complement our notion of infrastructure to go far beyond physical facilities to encompass the methods, business models, vehicle access and use models, data and labour models that create transportation value. Road surface, tracks, heavy transit vehicles, schedules and routes no longer explain everything. Current preoccupations obscure our understanding.

The reason that so few people understand prime time or surge pricing from transportation network companies (TNCs), such as Lyft or Uber, is because most people see chauffeurs as employees. But TNC drivers are not employees. They are volunteers. Prime time pricing calls them away from the dinner table or their beds to drive in peak hours or at tavern closing times when rides are needed. The absence of such a mechanism means taxis are unavailable when they are needed and circling pointlessly when they are not. Hence, the Lyft/Uber business model provides better service to its users, is cleaner for the city and encourages some users not to purchase a vehicle. It can also be cheaper than the bus in some ride-sharing circumstances.

Robotic vehicles, as indicated above, have the potential to make big problems worse, especially congestion, sprawl, and a demand for even more traditional infrastructure such as roads and parking facilities. They will almost certainly wipe out any residual value in financially stressed public bus systems. How should municipal and regional governments respond? City governments that fight robotic shared fleets like some fought Uber will lose. The cost per passenger kilometre will be a tiny fraction of the same passenger kilometre on a bus. It would make more sense for municipalities to engage in building massive shared fleets using PPP structures. Municipalities should plan to

disrupt transit head on in order to create public robotic fleet services in a way that ensures equitable access for every citizen – a concept still missing from the business model of TNCs. In today's world, at a time when the robotics are not yet ready, cities need to begin to create the pre-conditions for the future they want to become.

The Puzzle of Infrastructure for Robo-Cars

Two critical unknowns among all these uncertainties provide an important key to thinking about the infrastructure issues associated with robotic vehicles:

- Will the majority of autonomous vehicles be owned or shared?
- Will they gradually be mixed in with human-operated vehicles or will they somehow be isolated to carefully constrained applications?

Owned or shared: Private ownership will lead to large extant fleets. Since these vehicles will not require a licensed operator, young, old and disabled passengers can now utilize a dedicated vehicle without a family member acting as chauffer. Hence some families will see owning an additional vehicle as a very rational decision – and the powerful marketing forces of the automotive industry will always prefer the high-volume consumption model stoked by year-over-year feature creep to a shared-vehicle model.

Conversely, a shared-fleet model, if used by a majority of travellers, would mean smaller extant fleets, dramatically reduced parking infrastructure (and space) and less congestion. Ironically, although we might need only half as many vehicles – or fewer – to operate concurrently, there is no assumption of fewer vehicles manufactured since shared use means shorter life cycles – i.e., manufacturers will still make a similar (or greater) number of vehicles. The losers in this scenario are the makers of large shared vehicles (buses). Once freed of the labour costs, a larger fleet of smaller vehicles is far more flexible (and effective) for transit operations.

Freely mixed or constrained and isolated: There are many operational, social and liability complexities involved in freely mixing driver-out and driver-in vehicles on the same roadway. Even as these become solvable, there are other, far tougher acceptability issues. Furthermore, traditional automotive manufacturers will prefer the mixed model, as it justifies many years of feature-creep (safety features, intelligent features) and nurtures an ongoing preference for ownership. They will mine the rich marketing opportunities across the full spectrum of partial-to-complete robotic enablement taking advantage of any cultural predilection toward "my car, my way."

Using increasing automation as a gold mine for adding new and compelling features to each model year is the common commercial practice called "feature-creep." Clearly many automated and safety-related features should not be disparaged as feature-creep, but what is the same is the year-over-year business model of incrementalism to stoke envy and fuel sales. Traditional manufacturers will not abandon this underlying success formula to create new demand or competitive advantage.

New players such as Google/Alphabet, Apple and others promising full robotics sooner than the traditional players see feature-creep as unworkable. Astro Teller of Google X, the business division overseeing the Google automated vehicle, at a keynote given at the South by Southwest Interactive in March 2015, says this best:

> "Even though everyone who signed up for our (self-driving car) test swore up and down that they wouldn't do anything other than pay 100 per cent attention to the road, and knew that they'd be on camera the entire time … people do really stupid things when they're behind the wheel. They already do stupid things like texting when they're supposed to be 100 per cent in control … so imagine what happens when they think 'the car's got it covered.' It isn't pretty. Expecting a person to be a reliable backup for the system was a fallacy. Once people trust the system, they trust it.

> Our success was itself a failure. We came quickly to the conclusion that we needed to make it clear to ourselves that the human was not a reliable backup – the car had to always be able to handle the situation. And the best way to make that clear was to design a car with no steering wheel – a car that could drive itself all of the time."

This predicts that feature-creep will fail as vehicles become more automated but well before becoming driver-out, and a jump to full autonomy (Google's position) will be demanded. But we cannot move to pervasive robotics in a day. We still need to creep our way there as well.

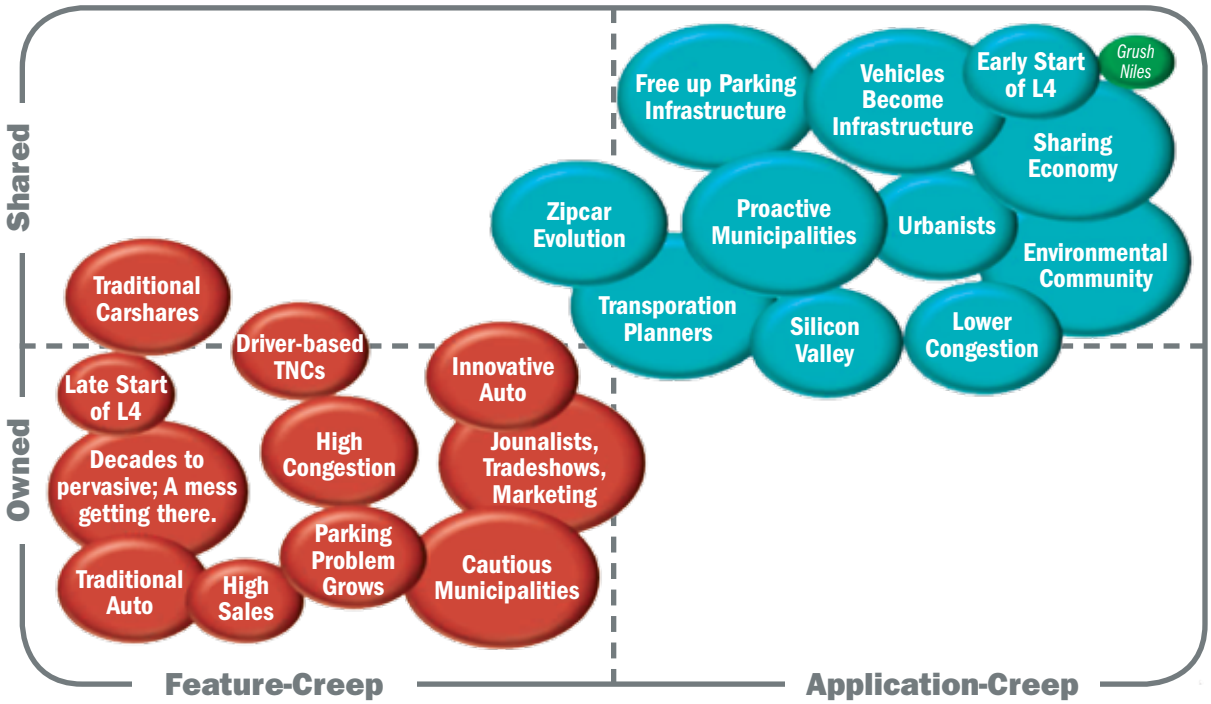
Teller's comment also predicts problems for mixing autonomous and non-autonomous vehicles. Note that all accident involvements for Google's autonomous vehicles to date have all been blamed on drivers of non-autonomous vehicles, which caused rear-end collisions. If mixing is not going to work, it would make much more sense to put robotic vehicles to work in constrained, unmixed applications.

For this, we introduce the concept of "application-creep," meaning we need to find safe, somewhat isolated applications from which we can start small and branch out. The European Union's CityMobil-guided, small-vehicle test project in several different cities is an early example – beginning cautiously, highly constrained, moving slowly and incorporating extreme oversight.

We know about numerous other small-scale applications: parking lot shuttles at airports that could be serviced by six- and eight-passenger vehicles running at modest speeds on clearly marked lanes and tightly constrained to regular service on regular routes. Human attendants would be eased out only gradually, both to provide comfort to early users and to help address labour attrition. Such applications are numerous and can be gradually expanded (the creep part) to longer routes, allowances to handle passenger requests by smartphone (more like a jitney than a shuttle). Following this, retirement communities could use such vehicles for local on demand trips including to local shopping, entertainment and worship.

Cities could begin with smaller urban bus routes at low speeds on constrained lanes at grade and without barriers, set up like bicycle lanes. These city systems would have the experience of the parking shuttles and the retirement communities to rely on. These city routes could expand in number, distance and flexibility until municipal transit is dominated by multi-sized autonomous vehicles. During the latter half of this shift, robo-taxi services could begin and would merge so that robotaxi and robo transit are a continuous service spectrum.

Figure 1: Sorting the stakeholders and concepts in modelling the future.



Innovation and Integration

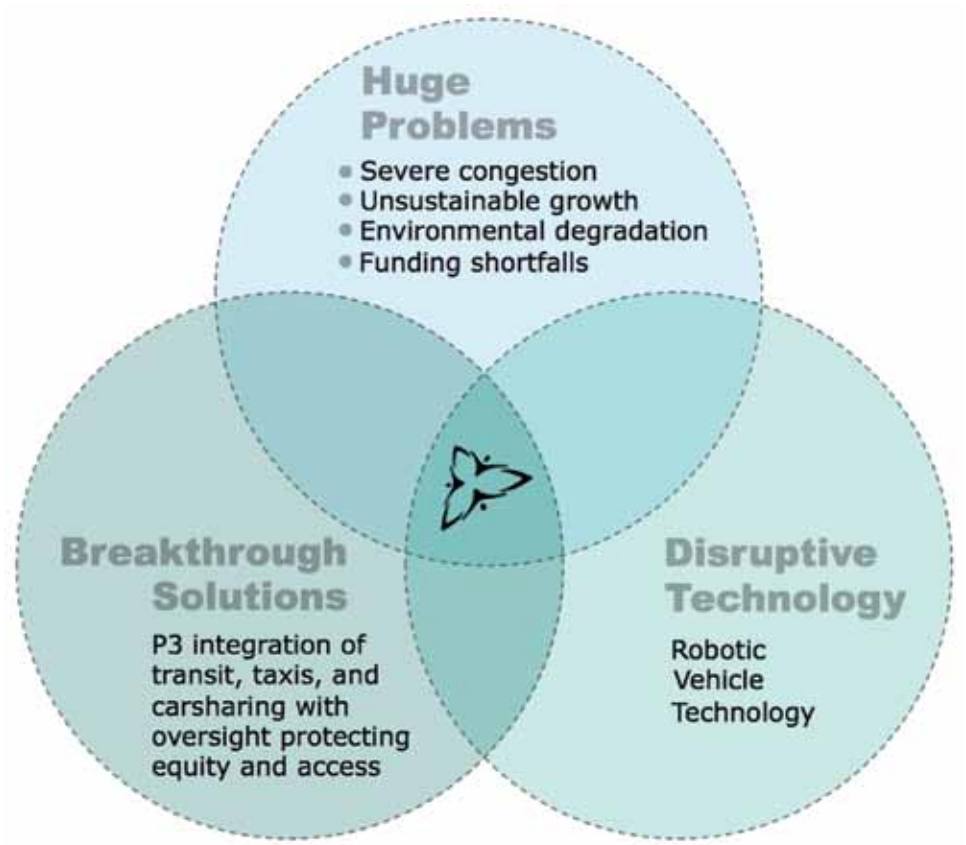
We can now reasonably begin the process of deciding how robotic mobility technology – especially where it involves sharable components – is to be deployed. We want to use this technology to completely transform surface transportation from transit that is cripplingly expensive and used across all trip types for roughly seven per cent of passenger kilometres in Canada. Shared vehicles (taxicabs, transportation network companies and carshare) although growing in number now, still produce statistically invisible passenger kilometres on a North American basis. Private vehicles – idle 95 per cent of the time – handle about 93 per cent of passenger kilometres in Canada, even higher in U.S.

GNA research indicates that setting a long-run target of 80 per cent of all passenger kilometres travelled by shared vehicles – i.e., vehicles that are part of a public, private or co-op fleet – that are busy from 40 to 80 hours instead of only 8.4 hours per week, would motivate an urban region to the point where a community of business and government leaders could begin to innovate just how such a fleet could be financed, maintained, managed and priced. Leaders could begin to figure out how to park this fleet off-peak, how to power it, how to re-purpose the liberated parking areas. Real estate interests in the community could begin a process to decide how to turn parking garages to other uses or re-purpose parking lots as parks. Public works departments and planners might turn street parking to bicycle paths. If community leaders do not set such an assertive target, automotive manufacturers will continue to roll out a high, personal-vehicle consumption model for us with unfortunate results.

Communities should start thinking now who would be best to deploy such fleets. Without going into specifics at this early stage, it's not too early to begin forums to discuss the incentive and regulatory structures that would fit Canadian values. Ideas should be collected regarding ownership models that would make sense. The alternatives of fleets owned and managed by large corporations (such as the Walmart model or franchised to family-run fleet clusters on the McDonald's model) should be put into planning scenarios.

Universities and professional groups should be asked to think about a role in sponsoring affinity fleets run by co-op transportation operators. What kinds of government guides for pricing, service, response times will be needed to maintain equity, or are the forces of the competitive market going to get it right soon enough? All this, and more, is worth discussing now in government-business forums.

Figure 2: Public-Private Partnerships for Innovation could create opportunities for regions to ensure access and equity to all and enormous opportunities for manufacturing and jobs.



The real disruption

It is the difference between the incremental feature-creep model now being pursued by auto manufacturers and the disruptive model of moving directly from driving to not driving pursued by Google, the EU and others that holds a key to the solution we are seeking. There are numerous problems of mixing robotic driven and human driven vehicles at any ratio – whether one per cent, 56 per cent or 99.3 per cent. Following the incremental, gradual mixed-traffic model leads to years of contention regarding traffic rules, overly cautious robotics, insurance liability, new legions of distracted drivers using robotics that operate 90 or 99 per cent of the time but not 100 per cent.

But if Canadian cities emphasized full-solution, application-creep innovation instead of preparing or waiting for household vehicle feature-creep, we could introduce less contentious, incremental improvements in controlled circumstances. If we used innovative business and financing models to replace and grow public (transit) passenger kilometres in increments safe for passengers and in ways that allow for thoughtful mitigation of the forthcoming, inevitable labour disruption, we could reduce the subsidization burden of transit, grow its ridership and attract drivers from household vehicles, in the same way TNCs do now. Rather than resisted, TNCs should be groomed and regulated to be integrated into a new hybrid solution of privately operated fleets governed for access and equity. It is the current case that however much Lyft and Uber may be good for young, carless travellers in our cities, TNC services are not designed to be available to the poorest travellers. Cities have a critical role to ensure access and equity even as current transit is disrupted.

With multiple service levels, related to things such as vehicle age, ride features, number of stops, ride sharing, convenience, comfort and more, a range of prices can be supported to be affordable for all users. There are ways with very little subsidy – very little would be best – to have transportation available to everyone at a level affordable to each. This is a preferred future.

There is also no way to guess all of the effects robotic mobility will have on the future of urban spatial distribution: density and sprawl. The harder truth is that what we believe we are able to predict about this new technology is less important than what we don't know or have not yet imagined. The things we surmise now about safety, productivity and labour disruption or the things we hope about congestion, energy efficiency and parking space recovery are easy enough to imagine. But there are many other things such as how we will locate ourselves in this re-enabled landscape, how transportation business and equity models will change or could be regulated, and how we will think about and finance the infrastructure needed to hold all this together, are much harder to think about.

And these things also need our attention. Starting now.

Bern Grush

John Niles

August 2015

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"As a result of cheaper labor, more manufacturing jobs that went overseas could return to the United States. At a time of increasing economic inequality, the higher productivity offered by advanced manufacturing often leads to higher wages for workers. (The Brookings report found that workers in advanced industries earned nearly double that of the average worker in other industries.) The innovation and increased productivity of advanced industries also hold the promise of cheaper and more widely available goods and services for the country as a whole, increasing standards of living across the board.

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"Muse, the company's first product, is a brain fitness tool that measures user's brain waves using seven finely calibrated electroencephalography (EEG) sensors – two on the forehead, two behind the ears working together with three reference sensors.

"The Muse application, which is available for download on Apple and Android mobile Devices, guides you through a focused-attention training exercise that generates real-time feedback. Muse: the brain sensing headband is available from retailers including Best Buy, in both Canada and the United States, Indigo, Amazon, Marbles, Frys and Gaiam.

"An entire ecosystem is building around Muse. SDKs for Android, iOS, Windows and Mac platforms are currently available for the developer community to build on. 'We're thrilled to note that Muse has been embraced by the medical community, which has found practical applications for the device to alleviate stress and anxiety in patients,' stated Lou Pino, Ph.D., Research Team Lead at InteraXon, adding that Muse is now used in brain research at Mayo Clinic, MIT, Berkeley, UCL and more than 40 other institutions across North America."

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