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)

Appendix D:
What are other experts and futurists saying?

A. Institute of Electrical and Electronics Engineers' (IEEE) 23 technologies to watch

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. They are listed below, with our technical explanations and trends commentary: [1]

1. Security Cross-Cutting Issues

The growth of large data repositories and emergence of data analytics have combined with intrusions by bad actors, governments and corporations to open a Pandora's box of issues. How can we balance security and privacy in this environment?

> In reflecting on the focus given this heading by the IEEE, there are Canadian infrastructure policy considerations as well. The attacks of September 11, 2001 brought the threat of terrorism to the awareness of politicians and the general public alike. It radically changed the priorities of governments, pushing them, as some would suggest, to want to know everything about everybody. This trend was underlined by the revelations of Edward Snowden of the massive domestic and international spying undertaken by the U.S. National Security Agency and the embarrassing admission of eavesdropping on our ally, German Chancellor Angela Merkel. But governments of all stripes – whether France following Charlie Hebdo massacre or our own Canadian government, following a range of disturbing domestic incidents – have given priority to security, law enforcement and counter-terrorism and the related infrastructure.
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> The growth of large data repositories and emergence of data analytics have combined with intrusions by governments, corporation and even online criminal organizations, to open a Pandora's box of issues, including personal privacy and consumer data security. How can we balance security and privacy in this environment? What are the infrastructure implications of these trends, for everything from hospitals to fibre-optic infrastructure?

2. Open Intellectual Property Movement

From open source software and standards to open-access publishing, the open IP movement is upon us. What are the implications?

3. Sustainability

Can electronic cars, LED lighting, new types of batteries and chips and increasing use of renewables combat rising energy use and an explosion in the uptake of computing?

4. Massively Online Open Courses (MOOCs)

MOOCs have the potential to transform the higher-education landscape, siphoning students from traditional universities and altering faculty and student roles. How significant will their impact be?

5. Quantum Computing

Constrained only by the laws of physics, quantum computing will potentially extend Moore's Law into the next decade. As commercial quantum computing comes within reach, new breakthroughs are occurring at an accelerating pace.

> Quantum computing: Essentially harnessing and exploiting laws of quantum mechanics to process information. A traditional computer uses long strings of "bits" which encode either a zero or a one. A quantum computer, on the other hand, uses quantum bits, or qubits. What's the difference? A qubit is a quantum system that encodes the zero and the one into two distinguishable quantum states. But, because qubits behave quantumly, we can capitalize on the phenomena of "superposition" and "entanglement."
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> Superposition is essentially the ability of a quantum system to be in multiple states at the same time — that is, something can be "here" and "there," or "up" and "down" at the same time.
>
> Entanglement is an extremely strong correlation that exists between quantum particles — so strong, in fact, that two or more quantum particles can be inextricably linked in perfect unison, even if separated by great distances. The particles remain perfectly correlated even if separated by great distances. The particles are so intrinsically connected, they can be said to "dance" in instantaneous, perfect unison, even when placed at opposite ends of the universe. This seemingly impossible connection inspired Einstein to describe entanglement as "spooky action at a distance." [2]
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> Moore's Law: The observation made in 1965 by Gordon Moore, co-founder of Intel, that the number of transistors per square inch on integrated circuits had doubled every year since the integrated circuit was invented. Moore predicted that this trend would continue for the foreseeable future. It has come to be equated to the doubling of computing power every 18 months, along with a corresponding decline in the cost and concern about the cost of data storage and processing.

6. Devices and Nanotechnology

It is clear that MEMS devices, nanoparticles and their use in applications are here to stay. Nanotechnology has already been useful in manufacturing sunscreen, tires and medical devices that can be swallowed.

> Micro-Electro-Mechanical Systems, or MEMS, is a technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (i.e., devices and structures) that are made using the techniques of microfabrication. The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimetres. Likewise, the types of MEMS devices can vary from relatively simple structures having no moving elements, to extremely complex electromechanical systems with multiple moving elements under the control of integrated microelectronics.

7. 3D Integrated Circuits

The transition from printed circuit boards to 3D-ICs is already underway in the mobile arena, and will eventually spread across the entire spectrum of IT products.

8. Universal Memory

Universal memory replacements for DRAM will cause a tectonic shift in architectures and software.

> Dynamic random-access memory (DRAM) is a type of random-access memory that stores each bit of data in a separate capacitor within an integrated circuit.

9. Multicore

By 2022, multicore will be everywhere, from wearable systems and smartphones to cameras, games, automobiles, cloud servers and exascale supercomputers.

> Also called multicore technology, it is a type of architecture where a single physical processor contains the core logic of two or more processors. These processors are packaged into a single integrated circuit (IC).

10. Photonics

Silicon photonics will be a fundamental technology to address the bandwidth, latency and energy challenges in the fabric of high-end systems.

> Silicon photonics is an evolving technology in which data is transferred among computer chips by optical rays (laser light), which can carry far more data in less time than electrical conductors can. The optical fibre is directly built into semiconductor chips to give IT "computing at the speed of light."

11. Networking and Interconnectivity

Developments at all levels of the network stack will continue to drive research and the Internet economy.

12. Software-defined Networks

OpenFlow and SDN will make networks more secure, transparent, flexible and functional.

> OpenFlow is a protocol that allows a server to tell network switches where to send packets. In a conventional network, each switch has proprietary software that tells it what to do. With OpenFlow, the packet-moving decisions are centralized, so that the network can be programmed independently of the individual switches and data centre gear.
>
> In a conventional switch, packet forwarding (the data path) and high-level routing (the control path) occur on the same device. An OpenFlow switch separates the data path from the control path. The data path portion resides on the switch itself; a separate controller makes high-level routing decisions. The switch and controller communicate by means of the OpenFlow protocol. This methodology, known as software-defined networking (SDN), allows for more effective use of network resources than is possible with traditional networks. OpenFlow has gained favor in applications such as VM (virtual machine) mobility, mission-critical networks and next generation IP-based mobile networks.

13. High-performance Computing

While some governments are focused on reaching exascale, some researchers are intent on moving HPC to the cloud.

> Exascale computing refers to computing systems capable of at least one exaFLOPS, or a billion, billion calculations per second. Such capacity represents a thousand fold increase over the first petascale computer that came into operation in 2008. (One exaflops is a thousand petaflops or a quintillion, 10^{18} floating point operations per second.) At a supercomputing conference in 2009, Computerworld projected exascale implementation by 2018. Enabling applications to fully exploit capabilities of Exascale computing systems is not straightforward.
>
> Exascale computing would be considered as a significant achievement in computer engineering, for it is believed to be the order of processing power of the human brain at neural level (functional might be lower). It is, for instance, the target power of the Human Brain Project.

14. Cloud Computing

By 2022, cloud will be more entrenched and more computing workloads run on the cloud.

15. The Internet of Things

From clothes that monitor our movements to smart homes and cities, the Internet of Things knows no bounds, except for our concerns about ensuring privacy amid such convenience.

16. Natural User Interfaces

The long-held dreams of computers that can interface with us through touch, gesture and speech are finally coming true, with more radical interfaces on the horizon.

17. 3D Printing

3D printing promises a revolution in fabrication, with many opportunities to produce designs that would have been prohibitively expensive.

18. Big Data and Analytics

The growing availability of data and demand for its insights holds great potential to improve many data-driven decisions.

19. Machine Learning and Intelligent Systems

Machine learning plays an increasingly important role in our lives, whether it's ranking search results, recommending products, or building better models of the environment.

20. Computer Vision and Pattern Recognition

Unlocking information in pictures and videos has had a major impact on consumers and more significant advances are in the pipeline.

21. Life Sciences

Technology has been pivotal in improving human and animal health and addressing threats to the environment.

22. Computational Biology and Bioinformatics

Vast amounts of data are enabling the improvement of human health and unravelling of the mysteries of life.

23. Medical Robotics

From autonomous delivery of hospital supplies to telemedicine and advanced prostheses, medical robotics has led to many life-saving innovations.[3]

> As noted elsewhere in this report, the advance of robots and robotics in the 21st century will have implications well beyond health care, including in the construction, maintenance and operation of infrastructure of all kinds.

B. "Mapping the Future: Mega-trends Library: Top Fifty Trends," Centre for Sensing and Mining the Future, Boston Consulting Group [4]

Demographic trends:

- Rise in aging population
- Longevity; Baby Boomers control 80 per cent of spending power for financial services and 50 per cent for discretionary expenditures; increased spending power among elderly in developed countries (housing, health care, appliances, financial services)
- Rise in immigration / ethnic diversity
- Increased role of women
- Rise in obesity and diet "lifestyle illness"
- Increase in focus on fitness, weight loss, surgery
- Rise in human mobility
- Rise in urbanization
- Megacities; new cities; increased demand for more infrastructure: roads, electricity, water, housing, health facilities, communications and construction materials

Consumer trends:

- Growth in trading up/trading down – "death of the middle"
- Consumers choosing higher categories (masstige) or lower prices; middle categories being squeezed (McDonald's, etc.)
- Rise in global sport and fitness (leisure trends)
- Sedentary work and lifestyle; global sporting events; recreation facilities demands
- Growth of customization
- Internet and globalization; meeting individual needs with mass-production efficiency
- Rise in organic
- Not just food products: apparel, cleaning products, personal care, pet food
- Need for production scale; improved documentation of provenance
- Rise in time compression / multi-tasking
- Distracted driving and its consequences; commuting patterns

- Rise in entertainment / celebrity
- Increasing brand affinity
- Impact on retail and e-commerce
- Rise in health and wellness concerns
- Preventative medicine; alternative medicine; fitness facilities

Economic Trends:

- Rise in outsourcing and off-shoring
- Rise of consolidations and M&A's
- Rise in productivity and performance focus
- Rise in R&D / innovation imperative
- R&D increasingly outside North America and Europe
- Commoditization
- Low margins, little brand loyalty, price and availability; effort to individualize to protect profit margins from commoditization
- Rise in capital flows to developing countries
- Rise in alternative investment vehicles (AIVs)
- Derivatives and other financial products, timber, energy futures, carbon credits
- Rise in socially responsible investing
- Environmentalism, consumer protection, quality, diversity
- Rise in e-trade and e-commerce
- Growth in regional trade blocs
- EU, NAFTA, ASEAN
- Rise in global divide
- Gaps in wealth, digital access, education, health outcomes, between and within countries
- Creation of a global elite
- More millionaires and billionaires, including emerging markets
- Rise of RDE (rapidly developing economies) challengers
- Displacing established major corporations
- Rise of India
- Rise of China
- Next billion consumers
- 500 million are presently low-income individuals in rapidly developing economies (RDEs); fluctuating incomes, need for infrastructure, retail demand
- Rising middle class
- Especially in RDEs; demand for durable goods (phones, automobiles, computers)
- War for talent
- Employers sourcing talent from around the world

Technology Trends:

- Rise in abundant bandwidth
- Impact of rise of large-demand uses (gaming, video-on-demand, cloud computing, VoIP, IPTV); sharp decline in the cost of computing; demand for "last mile" connectivity
- Rise in IT communities and Web 2.0
- YouTube, Facebook, Wikipedia
- Rise in new media
- Rise in networks

- Rise in convergence
- Rise in nanotechnology
- Medicine, clean technologies (bioremediation, clean energy, coatings, food, agriculture), consumer products (cosmetics, sunscreens)
- Rise of new materials / substitutes
- Lightweight materials; most promising: construction materials, polymers, ceramics, "smart" materials, nano-materials
- Rise of mobile electronic devices (MEDs)
- M-commerce; location-based services; biometrical identifiers for security
- Rise of RFID (radio-frequency identification) and sensor networks
- Monitoring, inventory audit, logistics tracking, authentication, theft control, payment systems, automatic information display; integrate sensor technology, network to monitor physical or environmental conditions
- Rise of wireless communication
- To enable GPS, satellite television
- Rise in smart devices
- Smart houses / appliances; predictive devices; GPS
- Rise in Internet access
- Rise in health care spending
- Pressure to reduce health care spending, by insurers and governments; shift to preventative medicine, chronic disease, primary care; impact of aging population, especially in developed economies
- Rise of biotech and proteomics (study of proteins)
- Biotech: medical (gene therapy), agricultural (transgenics), industrial (biodegradable plastics), environmental (waste treatment)
- Protemics: successor to genomics, cloning
- Rise in R&D / innovation challenge
- High cost of pharmaceutical innovation
- Rise in concern regarding energy supply
- Energy price volatility, including fossil fuels
- Increase in supply from wind, biofuels, hydroelectric, solar
- Increased energy demand, from transportation and industry
- Rise in demand for alternative energy sources
- Biofuels and biomass: wind, hydro, solar, wave power
- Impact of price of fossil fuels on alternative energy sources
- Rise of more sustainable forms of transportation
- Driven by cost of energy
- New fuel-systems (hydrogen, hybrids, batteries)
- Expanded use of public transport, cycling, high-speed rail

C. World Economic Forum, Geneva

For the 2015 World Economic forum, a consortium was commissioned to prepare an outline of global risks and major trends. The 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.[5]

To begin, the consortium identified 28 global economic, environmental, geo-political, societal and technological risks, as follows:

Economic risks:

1. Asset bubble in a major economy
2. Deflation in a major economy
3. Energy price shock to the global economy
4. Failure of a major financial mechanism or institution
5. Failure/shortfall of critical infrastructure
6. Fiscal crises in key economies
7. High structural unemployment or underemployment
8. Unmanageable inflation

Environmental risks:

9. Extreme weather events (e.g. floods, storms, etc.)
10. Failure of climate-change adaptation
11. Major biodiversity loss and ecosystem collapse (land or ocean)
12. Major natural catastrophes (e.g. earthquake, tsunami, volcanic eruption, geomagnetic storms)
13. Man-made environmental catastrophes (e.g. oil spill, radioactive contamination, etc.)

Geo-political risks:

14. Failure of national governance (e.g. corruption, illicit trade, organized crime, impunity, political deadlock, etc.)
15. Interstate conflict with regional consequences
16. Large-scale terrorist attacks
17. State collapse or crisis (e.g. civil conflict, military coup, failed states, etc.)
18. Weapons of mass destruction

Societal risks:

19. Failure of urban planning
20. Food crises
21. Large-scale involuntary migration
22. Profound social instability
23. Rapid and massive spread of infectious diseases
24. Water crises

Technological risks:

25. Breakdown of critical information infrastructure and networks
26. Large-scale cyber attacks
27. Massive incident of data fraud/theft
28. Massive and widespread misuse of technologies (e.g. 3D printing, artificial intelligence, geo-engineering, synthetic biology, etc.)

With these risks in view, they undertook a forward-looking assessment and cited a baker's dozen high-level megatrends that would influence the world economy and affect the identified risks.

Their 2015 trends were:

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

D. *No Ordinary Disruption: The Four Global Forces Breaking All the Trends*, by Richard Dobbs, James Manyika and Jonathan Woetzel; McKinsey & Co.: [6]

- Urbanization
- Pace of technological change
- Demographics (aging and immigration)
- Globalization and connectivity

E. "Pictures of the Future," The Magazine for Research and Innovation, Siemens AG

(Munich: Fall 2013); found at: http://www.siemens.com/innovation/apps/pof_microsite/_pof-fall-2013/_pdf/PoF-2-2013-E-doppel.pdf [7]

See also: Siemens Urban Projects: Tianjin, China Pictures of the Future, Spring, 2012, p. 90; Aspern, Vienna, Austria; Pictures of the Future, Fall 2013; pp. 16-20

F. *World's Top Global Mega Trends To 2025 and Implications to Business, Society and Cultures*, Iain Jawad; Frost & Sullivan

Another global trends-forecasting firm, Frost & Sullivan, prepared an intriguing list of megatrends. [8] Their list has a number of findings in common with the foregoing, but also with some new or differing insights.

The Frost & Sullivan list of 11 megatrends is:

- Urbanization – City as a Customer
- Smart is the New Green
- Social Trends: Gen Y, Middle Bulge, "Sheconomy," Geosocialization
- Connectivity and Convergence
- Bricks and Clicks
- Innovating to Zero
- New Business Models: Value for Many
- Economy: Beyond BRIC – The Next Game Changers
- Future Infrastructure Development

- Health, Wellness and Well Being
- Future of Energy
  Future of Mobility

See also: "New Mega Trends: Implications for our Future Lives," Sarwant Singh, Palgrave Macmillan;
Found at: http://www.palgrave.com/products/title.aspx?pid=577423

H. Ontario Centres of Excellence

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." [9]

From a variety of geographic locations across Ontario, it targets four sectors: advanced health technologies; advanced manufacturing; information, communications and digital media; and energy and the environment. With a board of directors that includes some of Canada's leading innovators and venture-capital investors, chaired by former OMERS CEO Michael Nobrega, the OCE has a variety of programs to advance its goals. These run the gamut from prizes, such as the $25,000 annual David McFadden Energy Entrepreneurship Challenge for young inventors, to the OCE's large annual "Discovery" showcase of Ontario innovation and investment opportunities. But its primary role is to identify, nurture, commercialize and invest in groundbreaking innovation in those four broad sectors.

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. The OCE provides an interesting, ground level window onto the potential impact of megatrends on infrastructure, right here in Ontario.

In the recent past, each of the OCE's four sectors yielded intriguing advances in commercialized research with implications for infrastructure:

- In the area of environment and energy, the OCE supported a new Ontario firm that uses clean energy and cloud-based software technology to power and integrate street infrastructure, like street lighting, CCTV security cameras, electronic parking meters and similar networked outdoor devices [10]; the OCE also promoted new production techniques and industrial re-purposing to enable large-scale conversion of fossil-fuel power generation to biomass [11];

- In the field of urban transportation, the OCE's research spanned from the micro to the macro: OCE supported a young business that uses advanced battery technology to make lightweight e-bikes a more practical option for urban cyclists. [12] In September 2014, the OCE also launched a major, multi-partner program called the "Connected Vehicle / Autonomous Vehicle (CVAV) Research Program for Road Vehicles," which we would know as the driverless car and intelligent transportation systems. The CVAV embraces research into: road transportation systems; road transportation systems data management; connected and autonomous in-vehicle technologies; and, improved road traffic management and operations. [13]

- In the construction field, along with the National Research Council and other partners, the OCE has invested in innovations such as hand-held measuring of the structural integrity of bridges and dams [14] and seismic protection for steel-frame high-rise buildings. [15]

- In the field of health care and sanitation, the OCE invested in Ontario innovations and patented processes that involved: anti-contamination, self-cleaning floor surfaces [16]; promoting health care hand-hygiene practices [17]; and, removing bio-solids, chemical and pharmaceutical contaminants from wastewater.[18]

These are clear examples of the way in which a social rate of return could be applied. The hospital system has to build in capacity to forestall spread of infection and to accommodate the one in 20 patients who contract hospital acquired infections (HAIs), such as the increasingly virulent MRSA [19] virus or the recurrent and pervasive C. difficile virus. Often modest technological fixes can shrink the diversion of health care resources and the costly physical plant required to house and treat these avoidable patients, to say nothing of the personal illness and risk endured by patients.

Likewise, a capacity to treat wastewater and to manage stormwater by targeted use of technology allows better priority setting and more efficient investment in refurbished and new water-management infrastructure. It also improves the safety and sustainability of our homes.

Endnotes

[1] Dejan Milojicic, *"Which technologies will dominate in 2022?," Wired* on-line magazine, Sept. 2014; found at: http://www.wired.com/2014/09/technologies-dominate-2022/
IEEE '2022 report' found at: http://www.computer.org/cms/Computer.org/ComputingNow/2022report.pdf

[2] University of Waterloo, Institute for Quantum Computing; found at: https://uwaterloo.ca/institute-for-quantum-computing/quantum-computing-101#What-is-quantum-computing

[3] For a Canadian perspective, see: *"Medicine in real time: the future is almost here: e-check-ins, medical history updated online – and the first fully digitized hospital,"* and *"Crash course in social media: Most doctors don't use Facebook or Twitter professionally. A university asks: Should they?" Macleans* magazine (Toronto: March 9, 2015); pp. 44, 46

[4] From slide deck *"Mapping the Future:megatrend mega-trends Library: Top Fifty Trends,"* Centre for Sensing and Mining the Future, Boston Consulting Group (New York, NY: 2015(?)); 92 slides

[5] *"Global Risks 2015: 10th Edition"* World Economic Forum (Geneva, Switzerland: 2015) 66 pp.;
Found at: www.weforum.org/risks

[6] *"No Ordinary Disruption: the Four Global Force breaking all the trends,"* Richard Dobbs, James Manyika, Jonathan Woetzel; McKinsey & Co., Public Affairs (New York: 2015); 277 pp.

[7] *"Pictures of the Future," The Magazine for Research and Innovation*, Siemens AG (Munich: Fall 2013);
Found at: http://www.siemens.com/innovation/apps/pof_microsite/_pof-fall-2013/_pdf/PoF-2-2013-E-doppel.pdf

[8] "*World's Top Global Mega Trends To 2025 and Implications to Business, Society and Cultures,"* Iain Jawad, Frost and Sullivan, Baltic Sea Region Investment Promotion Agencies Conference (Helsinki: June 2014); 30 slides

[9] *"ROI: Return on Innovation: Ontario Centres of Excellence Inc. Annual report 2013/2014,"* Ontario Centres of Excellence (Toronto: 2014)

[10] *Ibid., ROI, "Clear Blue Technologies*," pg. 14.

[11] *"Atikokan Bio-Energy Research Centre,"* Success Story: Environment and Clean Tech, OCE bulletins (Toronto: 2014)

[12] *Ibid., ROI, "Revelo Electric,"* pg. 18.

[13] *"Connected Vehicle / Autonomous Vehicle (CVAV) Research Program for Vehicles,"* OCE bulletin (Toronto: 2014)

[14] *"Giatec Scientific,"* Success Story: Advanced Manufacturing, OCE bulletin (Toronto: 2014)

[15] *"Cast ConneX Corporation,"* Success Story: Advanced Manufacturing, OCE bulletin (Toronto: 2014)

[16] *Ibid., ROI, "SunWash Technologies,"* pg. 20.

[17] *"HandyMetrics,"* Success Story: Advanced Health Technologies, OCE bulletins (Toronto: 2014); and, *ROI, "HandyMetrics*," pg. 21.

[18] *"Xogen Technologies Inc.,"* Success Story: Environment and Clean Tech, OCE bulletins (Toronto: 2014)

[19] Methicillin-resistant Staphylococcus aureus (MRSA)