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TOWARDS A MULTI-STAKEHOLDER INTERMODAL TRADE-TRANSPORTATION DATA-SHARING AND KNOWLEDGE EXCHANGE NETWORK

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RAPPORT DE PROJET

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Towards a multi-stakeholder Intermodal Trade-Transportation Data-Sharing and Knowledge Exchange Network*

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1 | EXECUTIVE SUMMARY

This report provides a transversal and multidisciplinary analysis of the challenges and opportunities regarding data interoperability and data sharing as they relate to the 'Great Lakes - St. Lawrence Seaway Trade Corridor' (GLSLTC)'s intermodal transportation and trade data strategy.

Our analytical work relies on 1) A review of the relevant documentation on the latest challenges to supply chains (SC), intermodal freight transport and international trade, identifying any databases that are to be used.; 2) A comparative review of selected relevant initiatives to give insights into the best practices in digital supply chains implemented in Canada, the United States, and the European Union.; 3) Interviews and discussions with experts from Transport Canada, Statistics Canada, the Canadian Centre on Transportation Data (CCTD), Global Affairs Canada, CIRANO's research community and four partner institutions to identify databases used in their research related to transportation and trade.

Its main findings can be summarized as follow:

1. GLSLTC is characterized by its critical scale, complexity, and strategic impact as North America's most vital trade corridor in the foreseeable further intensification of continental trade.
2. 4% of Canadian GDP is attributed to the Transportation and Logistics sector (2018): $1 trillion of goods are moved every year: Goods and services imports are equivalent to 33% of Canada's GDP and goods and services exports equivalent to 32%.
3. The transportation sector is a key contributor to the achievement of net-zero emissions commitment by 2050.
4. All sectors of the Canadian economy are affected by global supply chain disruptions.
5. Uncertainty and threats extend well beyond the COVID-19 pandemic.
6. "De-globalization" and increasing supply chain regionalization pressures are mounting.
7. Innovation and thus economic performance—increasingly hinges on the quantity and quality of data.
8. A new reality: data is transforming Canada's economy/society and is now at the center of global trade.
9. "Transport data is becoming less available: Canada needs to make data a priority for a national transportation strategy."
10. "How the Government of Canada collects, manages, and governs data—and how it accesses and shares data with other governments, sectors, and Canadians—must change."

Keywords: Great Lakes - St. Lawrence Seaway trade corridor, data science, intermodal transportation, data interoperability, supply chain

2 | INTRODUCTION

This report's main contribution is to bridge the gap between transportation, trade, and their economic and environmental impacts. Transportation is a set of complex systems and is, rightfully so, often analyzed in its own context. International trade is also a combination of different layers: resources, institutions, political risks, competitive advantages, comparative advantages, etc. Therefore, it is also often analyzed in its own context.

Between these two complex systems, there is essentially one variable that may create a bridge: distance. Indeed, one of the popular empirical strategies in international trade is to use gravity models. Within the important independent variables, distance is always a critical variable. But distance is often treated and considered in its geographic definition.

When adding the transportation block to the analysis, it is easy to realize that we can augment the gravity models with a more sophisticated and complex understanding of what distance really entails (Warin, Wunnava, and Janicki 2005; Warin et al. 2009). Suddenly, distance means transportation modes, intermodal transportation capacities, supply chain cybersecurity, supply chain decarbonization, etc.

In this report, we propose to combine both worlds to create an improved understanding of the dynamics at stake. This new framework that we propose also comes at a time when humanity is facing a radical change: the one resulting from the latest developments in Artificial Intelligence (AI). These developments are happening at multiple levels: first, the methodologies, in particular the neural network (philosophical) approach, and second, the data. Data are to be understood here in their complexity as well: massive, structured, unstructured, real-time, and digital. Besides the new AI, humans have access to unprecedented computing power. Moreover, we also have better, often open source, computing languages to integrate AI, data and computing power to help us make better decisions in an uncertain world (Bisson and Warin 2020; N. de Marcellis-Warin, Munoz, and Warin 2020).

Our framework thus consists of: (1) a context: the global technological revolution, (2) the bridge between transportation and international trade considerations, and (3) two shocks: Covid-19 and the climate crisis.

3 | CONTEXT

In this section, we start our multidisciplinary and transversal analysis with an overview of the accelerating global and domestic impacts of the COVID-19 pandemic on the significant trends and transformations at play in multiple aspects of the society and economy, including trade and supply chains.

We aim to provide a broad overview of the public policy responses regarding trends and risks.

3.1 | Economic priors

Our report stems from consultations with Transport Canada, which began in Ottawa on February 18, 2020, just before the last week of operating in a "normal" situation in Canada and around the world. The first COVID-19 case in Canada (Toronto) was confirmed on January 23, 2020, and in Québec (Montréal) on February 27. Peter Hall, EDC Chief Economist, in his introduction of the April 2020 Economic Outlook, stated that Canada was not prepared for this global pandemic:

> *"Canada isn't spared. We entered this crisis with poor fundamentals. Consumer savings were low, and debt-to-income spiked to an all-time-high 180%, helping to fund a cross-country housing bubble. Investment and trade were faltering, related to uncertainty in future global trade rules, the U.S.-China trade dispute and Brexit. Our higher trade dependence made us especially vulnerable to the virus-related stoppage of large portions of international trade. And the ravages inflicted on the oil industry have devastated a key Canadian GDP machine." (Hall 2020)*

This sober assessment is consistent with earlier findings of an Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada from the Council of Canadian Economies (CCA), who assessed in 2018 the latest evidence on Canada's R&D performance, combining up-to-date data with expert insights and analyses, benchmarking against the performance of other countries:

> *"In the 21st century, national prosperity, competitiveness, and well-being are inextricably linked to a country's capacity for R&D and innovation. Canada is competing intensely alongside other countries to foster the next wave of research advances and innovations." (Council of Canadian Academies, Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada, and Council of Canadian Academies 2018)*

The CCA report provided the following key findings (Council of Canadian Academies, Expert Panel on the State of Science and Technology and Industrial Research and Development in Canada, and Council of Canadian Academies 2018):

- Canada's international standing as a leading performer of research is challenged due to a sustained private and public R&D investment slide.

- Canada is not producing research at levels comparable to other leading countries on most enabling and strategic technologies, notably at a time of the platform economy (Marty and Warin 2020).
- Canadian research is comparatively less specialized and less esteemed in the natural sciences and engineering core fields.
- Canadian industrial R&D spending is declining and concentrated in intrinsically less R&D intensive industries. Canada has pockets of R&D strength across several industries, including ICT, aerospace, pharmaceuticals, and automotive, despite the poor overall performance.
- The barriers between innovation and wealth creation in Canada are more significant than those between R&D and innovation.
- Data limitations continue to constrain the assessment of R&D activity and excellence in Canada, particularly in industrial R&D and in the social sciences, arts, and humanities.
- The trajectory of Canada's R&D capacity is the reverse of our competitors, and it is a growing concern as the global economy becomes increasingly driven by technology.

The Global Innovation Index (GII) provides detailed metrics about the innovation performance of 131 countries and economies worldwide. Its 80 indicators explore a broad vision of innovation, including political environment, education, infrastructure, and business sophistication. The recent and jointly published 13th edition of the 2020 Global Innovation Index by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO) shows a worrisome discrepancy between Canada's innovation input and its output. While Canada scores high in input (ninth in most global rankings), the innovation performance output (22nd) is low (Cornell University, INSEAD, and WIPO 2020).

Canada's innovation and productivity continue to lag compared to peer countries, and the gap seems to be growing (OECD 2021c). Canada's total expenditure on research and development (R&D) has been steadily declining since the turn of the century, while that of all the other Group of Seven (G7) countries has been increasing.

The trend is identical when measuring Canadian R&D intensity[1]:

[1] OECD defines R&D intensity as domestic expenditure on R&D expressed as a percentage of GDP

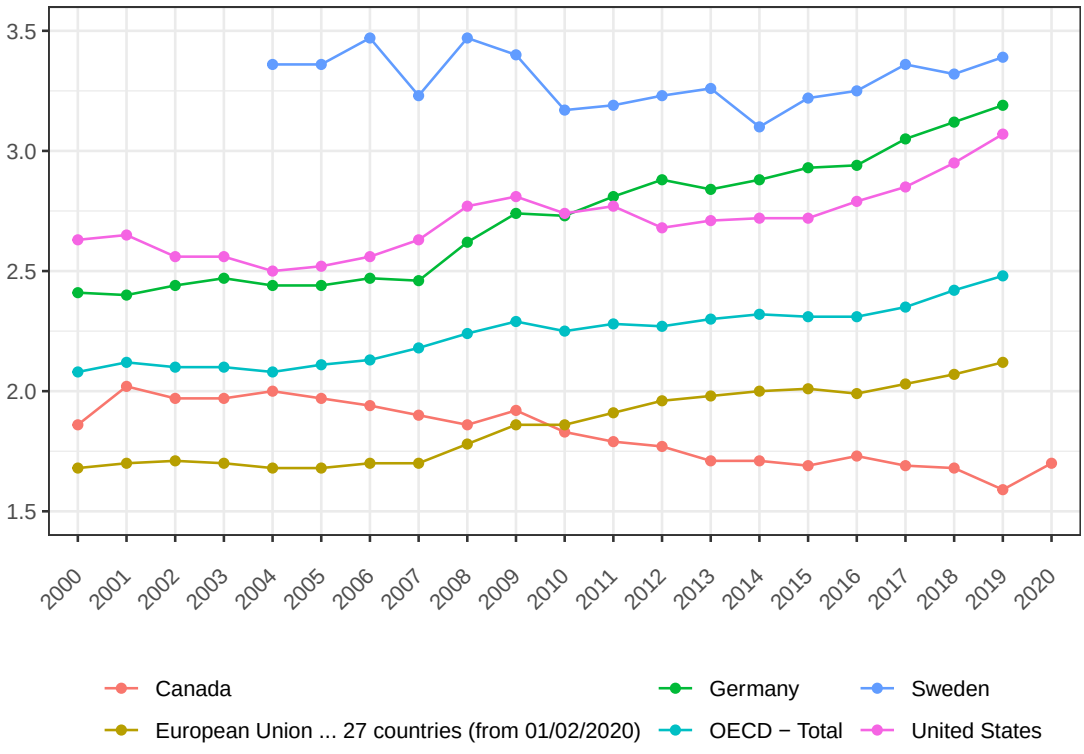


FIGURE 1 R and D intensity in OECD countries and other economies. Source: OECD Main Science and Technology Indicators Database, May 2021.

Canada's total expenditures on R&D (public, academic, private sector) as a percentage of Canada's total GDP grew over 20 years from 1981 to 2001 but has been in steady decline in the subsequent 18 years (Lowey 2021).

Moreover, when measuring the Canadian contribution to the ranking of the top 1,000 innovative companies globally, the Canadian economic structure produces innovation but does not seem to produce a proportionally respectable quantity, considering the size of its economy (Marty and Warin 2020; Warin 2020).

On the labor market dimension, employment fell to the lowest level since August 2020 (Statistics Canada 2021).

> *"Compared with February 2020, employment was down 858,000 in January, and COVID-related absences from work were up 529,000. Among Canadians who worked at least half their usual hours, the number working from home increased by nearly 700,000 to 5.4 million in January, surpassing the previous high of 5.1 million in April. The unemployment rate rose 0.6 percentage points to 9.4%, the highest rate since August 2020. The number of long-term unemployed (people who have been looking for work or who have been on temporary layoff for 27 weeks or more) remained at a record high (512,000). In January 2021, the labor underutilization rate rose 1.2 percentage points to 18.4%."*

Job recovery has slowed significantly in the face of a resurgence of COVID-19 cases and the reinstatement of restrictions. The employment outlook across industries has become increasingly polarized, with clear winners and losers. The job recovery is proceeding unevenly across the population, with a slower return to employment for women. This unevenness threatens to worsen inequalities within Canadian society.

While its economic activity dropped by 5.3 percent in 2020, Canada's real gross domestic product (GDP) is expected to grow by 5.3 percent in 2021 and 3.5 percent in 2022, respectively (The Conference Board of Canada 2021). Some other estimations are slightly different: a 6% global growth (5.0% Canada) for 2021 to 4.4% (4.7% Canada) in 2022. This reflects additional fiscal support in a few large economies, the anticipated vaccine-powered recovery in the second half of 2021, and continued adaptation of economic activity to subdued mobility. High uncertainty surrounds this outlook, related to the path of the pandemic, the effectiveness of policy support to provide a bridge to vaccine-powered normalization, and the evolution of financial conditions (IMF 2021). This increase brings output close to pre-crisis trends and, notably, the drop in the unemployment rate. Energy prices will affect consumer price inflation in the near term; core inflation will gradually increase.

In its April 1, 2021, Economic Outlook, EDC Economics made the following growth estimates for these selected developed economies (Hall 2021):

TABLE 1 Real GDP growth in a selection OECD countries. *Forecasts as of April 1, 2021

Real GDP Growth (Annual % change)	2020	2021*	2022*
Canada	-5.3	5.5	4.1
United States	-3.5	6.3	3.9
Eurozone	-6.8	4.3	4.4
Germany	-5.3	3.7	4.4
France	-8.2	5.6	4.2
Japan	-4.9	3.0	2.5
Total World	-3.5	6.4	5.4

Like global trade, Canadian trade was hit hard during shutdowns from March to May 2020 but rebounded quickly after that with a V-shape driven by restarting factories (Hall 2021).

There remains an exceptionally high degree of uncertainty around these forecasts due to many factors, including:

- the pandemic's severity and spread,
- its interdependence on containment efforts,
- the scale and efficacy of unprecedented policy responses.

3.2 | Challenges ahead

Like any country in this day and age, risks and uncertainties remain significant for Canada, notably around how quickly restrictions can be lifted as vaccine roll-outs proceed. There are also upside and downside risks in how rapidly households will unwind precautionary savings. Volatile global energy prices have discouraged oil and gas investments. On the upside, the fiscal stimulus in the United States now being implemented could bring a slight boost to Canadian

exports. The considerable epidemiological and economic uncertainty surrounding the COVID-19 pandemic teaches us that projections at 6 or 18 months are helpful, but they need to be considered with a higher margin of error than usual.

Furthermore, non-tariff barriers arising from interprovincial differences in product, service, and labour regulation seem to hamper the efficiency and productivity of Canada's business sector (OECD 2021b).

Structural reforms across federal, provincial, and territorial governments generally move in the recommended directions. However, their pace was slowed in 2020 because governments have been busy dealing with the COVID-19 crisis. More generally, Canada's highly decentralized system of government means that progress on structural reforms often requires coordinated action across governments. Consequently, building consensus and reaching an agreement on measures can be slow. On the other hand, it does facilitate policy innovations in one province (Medicare in the sixties, daycare in the nineties) that later become national policy. Canada must continue implementing structural reforms to boost productivity, diversify beyond traditional sectors, and transition to a greener and more equitable economy.

An emerging debate amongst economists is growing on inflation risks in advanced economies since the anticipated recovery stems from a negative aggregate supply shock (Roubini 2021). It is argued that current monetary and fiscal policies could lead to inflation or, worse, stagflation.

Another set of risks is about de-globalization and rising protectionism (e.g., rampant Buy American provisions), post-pandemic supply bottlenecks, the deepening Sino-American cold war and reshoring of foreign direct investments from low-cost China to higher-cost locations present potential adverse supply shocks, both as threats to potential growth and as possible factors driving up production costs.

Equally worrying is the demographic structure in both advanced and emerging economies. While elderly cohorts boost consumption by spending down their savings, new restrictions on migration will put upward pressure on labour costs.

Canada is an open economy that relies heavily on international trade for economic growth and quality of life. Canada's interdependence with the United States is imposed on us by geography (the aforementioned distance in the gravity-based trade models).

Canada's transportation system has faced significant disruptions in 2019 and 2020. Inclement weather, labour disputes, rail blockades, and the outbreak of COVID-19 have all put a strain on the system and its stakeholders (Transportation in Canada report, 2020). Despite these challenges, the system has remained resilient: in terms of the number of accidents, Canada continues to have one of the world's safest and secure transportation systems. The number of accidents stayed lower than or close to the ten-year average for all modes. Progress in fuel efficiency shows promising results, despite an overall increase in greenhouse gas emissions of 4% from 2008-2017. This increase is primarily due to more vehicles being on the road. Canada's transportation sector fared well despite a global decline in economic growth in 2019, transporting similar volumes to 2018. Nevertheless, challenges such as intermodal transportation optimization are still present.

The severity of this pandemic is forcing us to adapt and reinvent the way our institutions operate. It also compels us to adopt a new way of thinking and managing public and private organizations and our practices of working together.

The crisis and its response are accelerating three trends: the adoption of new technologies, the inevitable retreat of free-wheeling global supply chains, and the worrying rise of well-connected oligopolies (The Economist 2020).

This acceleration is evident in the growing importance of intangibles: Statistics Canada estimates that in 2018, the net value of data, databases, and data science assets was already equal to about half the value of all machinery and equipment in Canada. The prevalence of intangibles continues to increase as is the case for international trade, which is already marked by major structural transformations: a decrease in the trade intensity of goods; growth in trade in services; a greater intensity of knowledge and innovation (intangibles); increase in intra-regional trade; and a decrease in labour-cost arbitrage (Speer, Asselin, and Mendes 2020).

3.3 | Public policy responses in Canada

The COVID-19 crisis has forced all governments to adopt exceptional monetary and fiscal measures, including Canada. We summarize the Québec and Federal government budgets in chronological order of publication.

3.3.1 | Québec

In the context of the Great Lakes - St. Lawrence seaway, it is interesting to focus on Québec's situation. Following an unprecedented 5.2% decline in real GDP in 2020 caused by public health measures, the economic recovery in Québec has begun. Economic activity is expected to grow by 4.2% in 2021 and 4.0% in 2022, respectively. Despite the restart of the economy since last May, the effects of the crisis remain. However, the forecasts reflect a very high level of uncertainty. Economic growth will depend on the epidemiological situation, the progress of the vaccination campaign, and the support and recovery measures implemented.

TABLE 2 Quebec's economic growth forecasts. *Forecasts as of April 1, 2021

Real GDP Growth (% change)	2020	2021*	2022*
Québec	-5.2	4.2	4.0
Canada	-5.4	4.4	4.1
United States	-3.5	5.0	3.8
World	-3.5	5.3	4.3

In Budget 2021-2022, the government proposes accelerating growth and the transition to the new economy by announcing new measures totalling over $4 billion between now and 2025-2026. These initiatives aim to ("Québec is resilient and confident - Budget Plan" March 2021):

- increase productivity and stimulate business investment,
- create wealth through investments of $133.4 million in research infrastructure and centres,
- support the requalification of workers and get them back into the labor market,
- promote economic development in the regions,
- sustainably develop the economy.

Québec has significant public infrastructure needs. To meet them and restart the economy, the government has announced an increase of $4.5 billion over ten years. On average, investments under the 2021-2031 QIP increase to $135.0 billion. The 2021-2031 QIP allocates $14 billion to public transit and $28 billion to road maintenance.

In 2021 and 2022, the economic recovery will fuel an increase in both exports and imports. International supply chains will recover, and foreign demand will strengthen. In Québec, export growth (+3.1% in 2021, +4.5% in 2022) should be weaker than imports (+7.9% in 2021, +6.2% in 2022). In 2020, the decline in imports (-13.7%) was greater than exports (-10.5%). Accordingly, imports are expected to experience a bigger rebound, boosted by a strong increase in domestic demand.

The Canadian dollar's appreciation should foster imports and affect the international competitiveness of Québec's businesses.

3.3.2 | Federal

Economic activity during the second wave has proved more resilient than during the initial surge, showing that Canadians and businesses have adapted to operating under restrictions. While some peers saw contractions amid the second wave, Canada closed out 2020, far ahead of forecasters' mid-2020 predictions. With fiscal policy support exceeding 23% of GDP, Canada's response, including Budget 2021 investments, has been one of the largest and fastest among G7 countries (Federal budget, April 19, 2021).

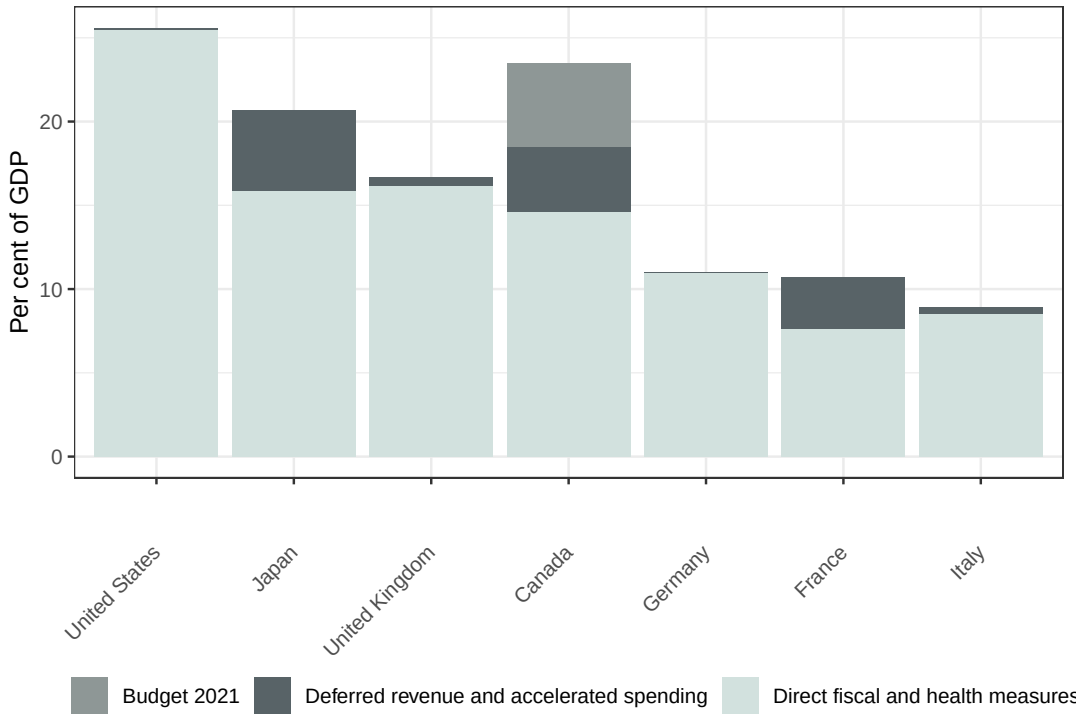
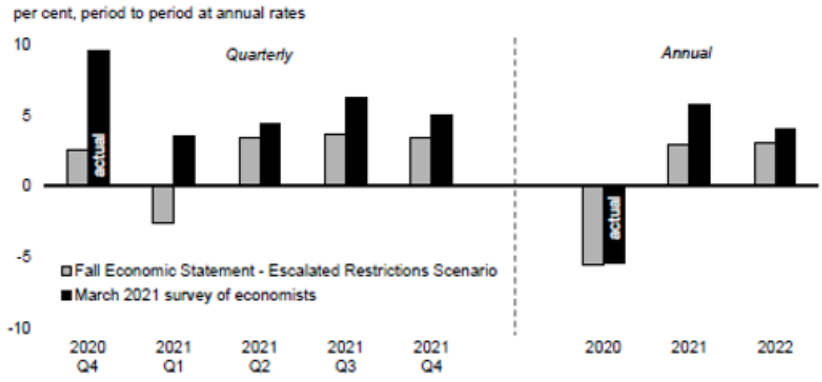


FIGURE 2 Fiscal policy support across G7 countries. Available at: https://www.budget.gc.ca/2021/report-rapport/overview-apercu-en.html

Early indications suggest that this momentum has carried over to the beginning of the year. Forecasts point to an increase in real GDP for the third quarter in a row, in stark contrast to expectations for second wave impacts set out in the Fall Economic Statement.

Altogether, economists have significantly revised their views for the recovery path since the Fall Economic Statement. Following a record decline of 5.4% in 2020, real GDP is expected to grow by 5.8% in 2021 and 4% in 2022. The projected level of real GDP by the end of 2022 is almost 2% higher than projected in the Fall Economic Statement.



Sources: Statistics Canada; Department of Finance Canada March 2021 survey of private sector economists; Department of Finance Canada calculations.

FIGURE 3 Canada's real GDP growth forecasts. Available at: https://www.budget.gc.ca/2021/report-rapport/overview-apercu-en.html

Support to a Digital Economy

Recognizing the fundamental shifts underway in our society, the government introduced a new Digital Charter in 2020 that seeks to protect better Canadians' privacy, security, and personal data, thus building trust and confidence in the digital economy.

To ensure that Canadian businesses can keep pace with this digital transformation and are part of this growth, Budget 2021 includes measures to ensure businesses and workers in every region of the country have access to fast, reliable internet. It also has measures to ensure that the digital economy is fair and well reported on. A digital economy that serves and protects Canadians and Canadian businesses is vital for long-term growth.

Establishment of a New Data Commissioner

- Budget 2021 proposes to provide $17.6 million over five years, starting in 2021-22, and $3.4 million per year ongoing, to create a Data Commissioner. The Data Commissioner would inform government and business approaches to data-driven issues in order to help protect people's data and encourage innovation in the digital marketplace.
- Budget 2021 also proposes to provide $8.4 million over five years, starting in 2021-22, and $2.3 million ongoing, to the Standards Council of Canada to continue its work to advance industry-wide data governance standards.

Enhancing Business Condition Data: The government introduced the Canadian Survey of Business Conditions in April 2020 to promptly measure business and economic indicators and better understand changing business conditions. To further this work with partners and enhance the availability of real-time business indicator data, Budget 2021 proposes to provide up to $5 million over two years, starting in 2021-22, to Statistics Canada in order to work with partners on enhancing the availability of business condition data, so as to ensure that the government's support measures are responsive to the needs of Canadian businesses and entrepreneurs.

Accelerating Canada's Net-zero Transformation Through Innovation

Budget 2021 proposes to provide $5 billion over seven years (cash basis), starting in 2021-22, to the Net Zero Accelerator. Building on the support for the Net Zero Accelerator announced in the strengthened climate plan, this funding would allow the government to provide up to $8 billion of support for projects that will help reduce domestic greenhouse gas emissions across the Canadian economy. The Net Zero Accelerator works to cut pollution, spur clean technology innovations, attract significant investments, create good middle-class jobs, and foster the development of critical supply chains to ensure Canadian industries and workers can use their low-carbon advantage to compete and win.

Building Infrastructure to Boost Trade and Borders modernization

Budget 2021 proposes investments in physical and digital infrastructure and other measures to transform Canada's borders and ensure that trade and travel continue to drive Canada's economy. Canada needs to address capacity constraints, bottlenecks, and inefficiencies in its transportation infrastructure to support a robust and quick recovery. To reduce barriers to trade, help our businesses grow, create jobs, and ensure our companies are competitive in the recovery: Budget 2021 proposes to invest $1.9 billion over four years, starting in 2021-22, to recapitalize the National Trade Corridors Fund. This funding could attract approximately $2.7 billion from private and other public sector partners, resulting in total investments of $4.6 billion. This would spur investments in much-needed enhancements to our roads, rail, and shipping routes, build long-term resilience for the Canadian economy, and support internal trade. It would make Canada's transportation system more fluid, supporting economic recovery and increasing prosperity across Canada. Alleviating bottlenecks and congestion will also reduce greenhouse gas emissions in Canada.

The safe and timely flow of people and goods across borders is integral to Canada's economic recovery. A modern border should facilitate seamless and secure travel and trade while protecting Canada from public health and security threats in the years ahead. Budget 2021 proposes to provide $656.1 million over five years, beginning in 2021-22, and $123.8 million ongoing, to the Canada Border Services Agency (CBSA) in order to modernize Canada's borders. Funding will transform the border experience for travellers through touchless and automated interactions, enhance CBSA's ability to detect contraband, and help protect the integrity of Canada's border infrastructure. Funding will also support three Canadian preclearance pilots in the United States that would enable customs and immigration inspections to be completed before goods and travelers enter Canada. These initiatives will help preserve Canada's borders' security and integrity while expediting legitimate travel and trade flow.

4 | TRADE CORRIDORS IN CANADA

Canada's history and future are linked to transport given its geography and population size spread over a vast landmass. The St-Lawrence Seaway is a bi-national system of locks, canals, and channels in Canada and the United States. It permits oceangoing vessels to travel from the Atlantic Ocean to the Great Lakes of North America, as far as Duluth, Minnesota. This waterway system has a long history. It was preceded by several other canals and locks, which already allowed transit in 1871 of oceanic vessels on the Saint Lawrence River. The first proposals for a bi-national comprehensive deep waterway along the Saint Lawrence were made in the 1890s. In the following decades, developers proposed a hydropower project; the various governments and seaway supporters believed the deeper water to be created by the hydro project was necessary to make the seaway channels feasible for oceangoing ships.

4.1 | Transportation Strategy

The current Transportation 2030 strategy of the Canadian Government promotes a safe, secure, green, innovative, and integrated transportation system. It highlights "Trade Corridors to Global Markets" as one of its five focus themes[2]. The broad consultations that took place in 2016 in the lead up to the launch of this strategic plan highlighted several critical challenges, including:

- Cost inefficiencies hurt Canada's ability to compete globally
- The costs of domestic freight transportation significantly affect industrial investments
- Beyond infrastructure investment, Canada must use innovation, policy, regulations, and creativity to improve the efficiency of supply chains
- We must adopt a national and system-wide way of looking at things to identify problems
- However, we must also keep in mind the individual needs of shippers, as there may not always be one fix for all sectors
- Transport data is becoming less available, but Canada needs to make data a priority for a national transportation strategy

The Government is committed to addressing these challenges through the Transportation 2030 strategy:

- Support the movement of goods and people by investing more than $180 billion in infrastructure over 12 years as part of the Investing in Canada Plan
- Use new ways to collect and analyze data
- Make sure that data is available to all who operate, oversee, and use the transportation system
- Look at new ways to finance transportation infrastructure projects in partnership with other levels of Government and the private sector
- Make infrastructure investments to address bottlenecks in important trade corridors, including rail export corridors
- Work on greater transparency in the rail transportation supply chain
- Take a more balanced approach for rail stakeholders

[2] Five themes on which Transportation 2030 strategy focuses: 1/ The Traveller; 2/ Safer Transportation; 3/ Green and Innovative Transportation; 4/ Waterways, Coasts, and the North; 5/ Trade Corridors to Global Markets.

- Support a more competitive and efficient rail sector
- Make sure our actions support work on government priorities, such as:
- Canada's progressive trade and investment plan
- A pan-Canadian framework on clean growth and climate change
- A national innovation agenda

Less than ten years before the launch of this plan, the 2007 national policy framework for Strategic gateways and trade corridors recognized the vital importance of the Great Lakes - St. Lawrence trade corridor. The two central Canadian provinces represent approximately 60% of Canada's exports and gross domestic product. Significant transportation infrastructure assets of all modes and four of Canada's six highest-volume border crossings underpin this economic heartland. Optimal use and development of the region's transportation system were highlighted as essential to support Canada's current and future commerce relationship with the U.S. and other trade partners. They promised significant gains in competitiveness and sustainability.

Since 2007, Transport Canada has developed and implemented an analytical framework to support the various gateways in collaboration with provinces and other public and private stakeholders. Substantial analysis has been conducted to identify the multimodal transportation system's capacity and demand, and significant knowledge has been gained. This analytical framework has led to identifying issues and bottlenecks affecting the efficient flow of international freight and the transportation system's competitiveness.

In this respect, the comprehensive study on "Multimodal Freight Transportation Within the Great Lakes - St. Lawrence Basin" (National Academies of Sciences, Engineering, and Medicine 2012) published in 2012 by the Transportation Research Board (TRB) deserves consideration. The study describes the multimodal freight transportation system as of 2012 within the bi-national region (i.e., Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio, Pennsylvania, New York, Ontario, and Quebec) and its importance to regional, U.S., and Canadian economies.

The TRB report also analyzes the system's overall performance and related opportunities and constraints to improve performance and meet projected freight flows and includes:

- an analysis of each mode's capacity and the major commodities each of them moves;
- the barriers and constraints that impact each mode's ability to move cargo;
- the performance implications in terms of major commodity supply chains (coal, automotive parts, and machinery, containerized consumer goods, grains, and iron ore);
- a strategic freight planning process for multimodal transport chain performance going forward.

The 2012 study suggested significant research work could be undertaken, focused in three intertwined areas: data development and sharing, collaboration and coordination, and the development of a strategic framework to guide these efforts and freight transportation planning:

> *"More research on multimodal and supply–chain–specific performance matters is particularly needed to inform a coordinated approach to strategic policy and investment decisions that are in line with regional, national, and continental transportation policy objectives." (p.77)*

Furthermore, the observations from this 2012 study as they relate to freight data availability are very much topical:

> *"Data remains a major limitation for regional freight planning in the GLSLB, particularly freight transportation performance data. The availability of Freight Analysis Framework (FAF) data in the U.S., and to a lesser extent, Statistics Canada freight transportation data in Canada, is a step forward. Making U.S. and Canadian freight transportation data available in an integrated, consistent form and from one central repository represents an opportunity. Freight transportation performance data (e.g., transit time, cost, reliability of alternative corridors, etc.) remains a significant gap and would be particularly valuable in informing regional freight plans." (p.67)*

While not specific to the GLSLB, Transport Canada has developed fluidity indicators to measure supply-chain transit times for the movement of containerized imports and grain exports from the port of loading to end market and vice versa through key gateways and corridors. The U.S. DOT is reportedly developing similar performance indicators.

> *"Several private-sector supply-chain actors, including carriers and freight forwarders, develop and track performance data but seldom make it public and have little incentive to do so at present. Examples include the performance metrics used by Canadian National (C.N.) and its supply-chain partners, which focus particularly on transit time, dwell times, and so forth throughout the transport chain (per their Service Level Agreements [SLAs]). There is no question that such performance data, in aggregate form, would be very valuable for freight planners. It is worth investigating opportunities to access this data, and related incentives for private carriers to share this data, in particular information concerning the first and last mile of the supply chain."*

The analysis developed in the "Multimodal Freight Transportation Within the Great Lakes - St. Lawrence Basin" provides guidance on opportunities to improve the planning process vis-à-vis the multimodal freight transportation system in the region, as well as initiatives to improve its performance. One of the key messages is the need for a well-informed, coordinated, and strategic approach for the improvement of the GLSLB multimodal performance freight transportation system.

4.2 | Supply Chain and Intermodal Transportation

Global supply chain networks have demonstrated remarkable resilience in the face of worldwide supply and demand-side disruptions during the pandemic. These disruptions are a recurring fact of life and are likely to be more frequent. Ongoing supply chain disruption is a cost of doing business today, and uncertainty is expected to continue due in part to external risks as well as the possibility of increased disruption frequency. This context calls for a push towards greater supply-chain sustainability and technological advances in demand-supply chains that are resilient, flexible, relatively simple, and transparent.

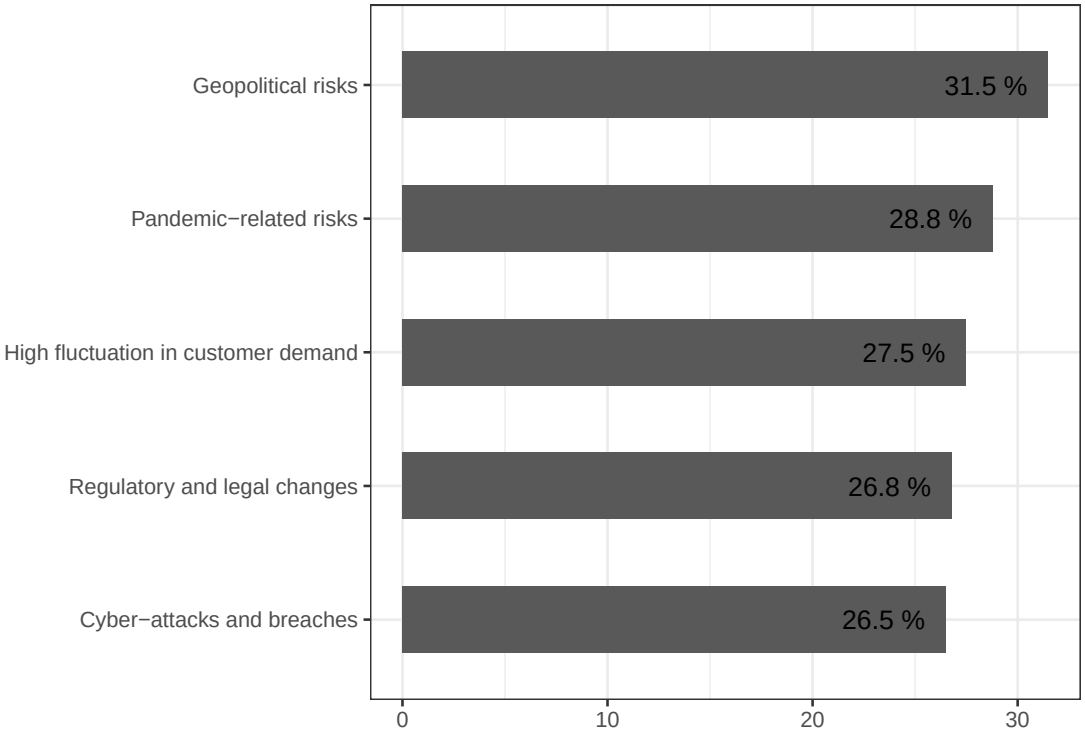


FIGURE 4 The top five external risk factors most likely to impact supply chains up to 2025. Source: The Economist Intelligence Unit. (2021).

A consensus of industry experts anticipates that supply chains in coming years will become even more "networked" than they are today for two primary reasons (The Economist Intelligence Unit 2021):

1/ As digital advances continue to reduce communication and coordination costs, companies will find it easier and more efficient to secure external solutions than inventing solutions in-house.

2/ Most companies find it increasingly challenging to sustain best-in-class internal supply chain competencies across a diverse set of emerging digital technologies that range from the "Internet of Things" to sophisticated artificial intelligence algorithms.

Effectively managing and coordinating tomorrow's networked supply chains will require organizations to develop and adopt more structured collaboration models, scalable approaches to enabling true data transparency, and frictionless co-creation largely absent in today's collaboration models.

The regionalization of supply chains was well underway before COVID-19 to increase speed to market in addition to reducing logistics cost and time (Lund et al. 2020). COVID-19 has accelerated these trends already in motion. Over 90% of executives plan to invest in supply chain resilience.

Building resilience is a high priority among supply chain executives – and actions taken in its support could shift the geography of trade: $2.9 and $4.6 trillion in annual trade may shift to new locations.

The logistics and transportation sector is an essential driver of a country's and firms' competitiveness because it enables connections between domestic and international markets. The performance of a country's transportation and logistics sector correlates directly with its measure of economic development (The World Bank 2017). Globally, the logistics market was estimated to have surpassed $4 trillion, or roughly 10-12% of the world's GDP (Forbes Insights 2018).

Canada's long-term growth, competitiveness, and sustainability depend on embracing supply chains transformations that are responsive, integrated, and intelligent. In 2019, the transportation and warehousing sector's gross domestic product increased faster (3.2%) than all other industries in Canada (2.0%). International trade was $1,195 billion, a 1.2% increase from 2018 (The World Bank 2017).

Canada's transportation infrastructure quality combined with its trade corridors' efficiency is critical to Canadian firms' successes in the global marketplace. Canada's supply chain enables $1 trillion worth of goods movement and is ranked among the top 20 nations in the World Bank's Logistics Performance Index (SCMA 2016).

The Canadian supply chain provides close to a million jobs and makes up 10% of itsGDP. Supply-chain activities transform and move products and services, creating value for firms, suppliers, distributors, and consumers. Supply chains are crucial to growth, competitiveness, and sustainability. As the backbone of the economy and trade, supply chains propel all industries (SCMA 2016).

In 2015, Canada's supply chain management sector had an estimated value of $162.1 B, almost six times the size of the agriculture sector ($27.6 B), and slightly less than the manufacturing sector ($175.1 B). In 2015, the total exports value of goods from Canada was $525 B, with the energy sector having the highest share of these exports (24.2%), followed by metals, ores and industrial products (11.6%), agri-food (9.6%), and forestry (5.5%) (SCMA 2016).

The pandemic has seriously impacted Canada's trade and supply chains: our energy exports (the highest share of Canadian goods exports) declined 21% in March 2020 compared to March 2019. COVID-19 significantly impacted industries reliant on international supply chains: a 23% decline for automotive products exports, 11% decline for machinery exports, and 26% decline for electronics exports (Global Affairs Canada 2020). Meanwhile, Canada's agri-culture exports improved by 13% in March 2020 compared to March 2019.

The disruption in supply chains caused by COVID-19 is readily apparent. From raw materials to finished goods, the operational effectiveness of distribution chains has been impacted by introducing social distancing measures and "lockdowns" of various kinds. Due to the unavailability of labour or material inputs, slowdowns are inevitable as the virus spreads. Transportation authorities' preventive measures have curtailed export and import activity, such as mandatory ship quarantines and vessels' return delays. The impact on Chinese shipping has left a shortfall of hundreds of thousands of shipping containers, which risks reducing millions of tons of shipping capacity.

The danger of protracted disruption of global supply chains was ranked at number seven, with 42.1% of risk experts surveyed worried about this economic risk (World Economic Forum 2020).

The pandemic forces Transport Canada to reassess current supply chains' strengths and weaknesses in domestic and international trade. This reassessment is being done to improve Canadian supply chains' efficiency, particularly regarding the multimodal integration of transportation modes and integrating goods and services in their technological and geographic dimensions. This reassessment should also add a risk analysis dimension identifying the value chains' fragilities.

The pandemic is accelerating the transformation of supply chains in North America. The following trends and needs of transformation for SC can be highlighted (De Muynck 2020):

- Increased public scrutiny of supply chain stability and workplace safety, especially in physical frontline operations
- Increased visibility of supply chains, their agility, and resilience become equal considerations to cost, efficiency, and quality
- Change in consumer behaviour: permanent transition of some spending to e-commerce channels versus store purchases.
- Increased demand for the last mile also affects the first and middle mile
- Increasing use of technology
- Increased use of digitized freight networks
- Circular economy agenda reinforced
- Supply chain networks further diversify beyond reliance on single countries and regions to ensure greater resilience
- Increasing demand for transport
- cybersecurity

Canada ranked 32nd in 2019 and scored 65.7 (far below the 100 level in terms of transportation infrastructure, an ideal state where an index component ceases to be a constraint to productivity growth) concerning the World Economic Forum's Global Competitiveness Index, a yearly indicator of a country's performance based on productivity and economic growth measures. Transportation infrastructure is included in calculating the Index and can be used for comparing the transportation infrastructure quality in Canada to other countries (Schwab and Zahidi 2020).

While our heavy supply chain dependence on China for medical manufacturing has been apparent for about two decades, many observers and policymakers agree that the pandemic reveals just how vulnerable we are as we must rely on Beijing and other countries to help provide the necessary tools to combat the pathogen (Dudoit 2020).

Digital technologies and artificial intelligence are also disrupting supply chains. The massive amounts of data supply chains generate can create enormous business value. Innovation is a necessity. Big data is driving a revolution in machine learning, operations research, and business analytics. Autonomous systems, robotics, blockchain, and the IoT offer new ways to track and trade goods and services.

Now, technology allows the implementation of a seamless data flow through supply chains, including the public authorities and businesses, representing all modalities, logistics services, shippers, cargo types, and last-mile (urban) delivery. All these stakeholders are thus enabled to interconnect within one common data-sharing environment to effectively exchange information they require to improve their performance and optimize operational processes.

Quebec and Ontario lie at the heart of Canada and North America's supply chains and operate some of the most highly advanced, complex, and globally connected supply chain systems in the world, e.g., in automotive and aerospace. The region boasts Canada's most advanced infrastructure, with world-class airports and ports, alongside some of North America's busiest road, rail, and sea networks.

The region supports Canada's densest spectrum of industrial players, accounting for ~60% of industrial GDP (National Academies of Sciences, Engineering, and Medicine 2012).

Montreal and Toronto are the epicentres of a globally recognized revolution in deep learning that has attracted hundreds of millions of dollars of investment from multinationals (Google, Facebook, Microsoft…). The supply chain is trade. In 2015, Canada's transporters moved $1 trillion worth of goods and $525 billion in exports (SCMA 2016).

While the Great Lakes - St. Lawrence Trade Corridor presents significant competitive advantages, including a dense spectrum of industrial players connected to local/global economies, world-class centers of excellence and innovation-focused players, and a unique concentration of research and technological leadership, some gaps currently slow the adoption of "smart" intermodal transport and supply chains systems such as:

- Data Technology compatibility: Datasets are often siloed within sectors or applicable only to a transportation mode. Lack of interoperability limits synergies and collaboration.
- Subscale barriers: Canada's economy is 10x smaller than the U.S.'s, with an abundance of SMEs (90% of private-sector jobs). This situation restricts large-scale innovation and creates a productivity gap (~45% for small vs. large manufacturing firms) (Innovation 2019).
- Shortage of talent: digital literacy is not widespread, limiting the adoption of human-in-the-loop technology. Only approximately 50% of Canadians have basic digital problem-solving skills. Around 70,000 skilled supply chains jobs are vacant, and demand will only increase (Scale AI 2017).
- Low diffusion of innovation: Canada's SMEs lack available investment to scale up. Only 1.4% of mid-sized Canadian companies grow over 500 employees (Scale AI 2017).

4.3 | Digital transformation in the transportation sector

The volume and variety of data are growing exponentially, making data hard to process using conventional database management tools. Data is the lifeblood of economic development: it is the basis for many new products and services, driving productivity and resource efficiency gains across all sectors of the economy, allowing for more personalized products and services, and enabling better policymaking and upgrading government services.

Data is reshaping the way we produce, consume, and live. It is reshaping the business models of our societies with the development of the platform economy (N. de Marcellis-Warin, Munoz, and Warin 2020; Marty and Warin 2020). Benefits will be felt in every aspect of our lives, ranging from more conscious energy consumption, material, and food traceability to healthier lives and better healthcare. Moreover, making more data available and improving how data is used is essential for tackling societal, climate, and environment-related challenges, contributing to healthier, more prosperous, and more sustainable societies. Data availability is essential for training artificial intelligence systems with products and services rapidly.

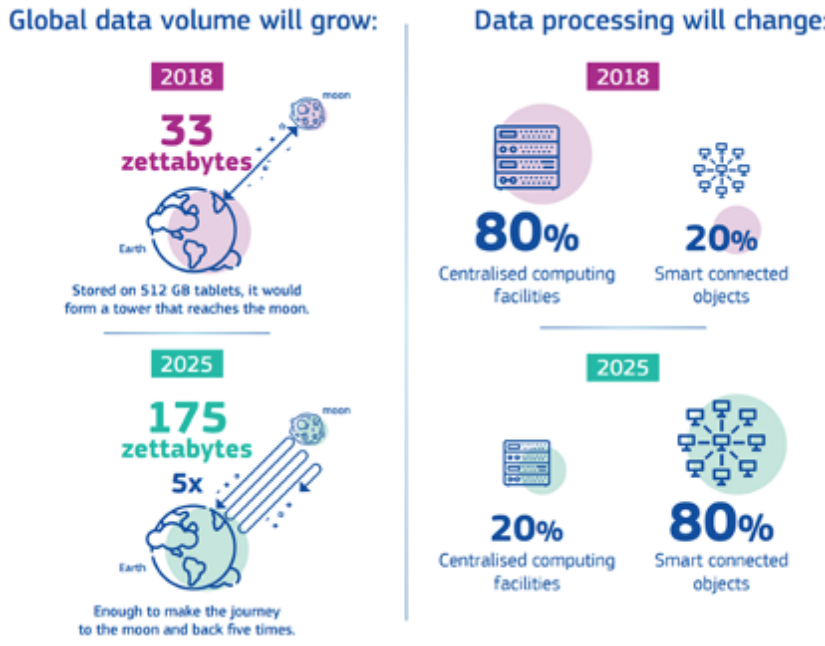


FIGURE 5 Anticipated growth of global data production. Source: European Commission (2020, February). The European Data Strategy: Shaping Europe's Digital Future. European Union, 2020.

- The volume of data produced globally is proliferating, from 33 zettabytes in 2018 to an expected 175 zettabytes in 2025.
- How data is stored and processed will change dramatically over the coming five years.
- Today, 80% of the processing and analysis of data occurs in data centres and centralized computing facilities, and 20% in smart connected objects, such as cars, home appliances or manufacturing robots, and computing facilities close to the user ('edge computing').
- By 2025, these proportions are likely to be inverted.
- Statistics Canada estimates that Canadians invested as much as $40 billion during 2018 in data, databases, and data science – greater than the total investment in industrial machinery, transportation equipment, and research and development (European Commission 2020).

Digital transformation is particularly hard for organizations in the public sector. In a McKinsey and Company article, Ghia et al. (2021) identify the following challenges for the implementation of data and analytics transformation in the public sector: the scale of many public-sector organizations; bureaucracy and risk aversion leading to restrictions and lengthy processes in technology integration; competition with the private sector to hire talents; culture; and frequently changing leadership.

Digital transformation in the public sector is at the heart of the Data Strategy Roadmap for the Federal Public Service (Government of Canada 2018a) published in the 2018 Report to the Clerk of the Privy Council:

- The volume of data that governments, businesses, and Canadians produce is growing exponentially, animated by digital technologies.
- Organizations are changing their business models, building new expertise, and devising new ways of managing and unlocking their data value.
- Governments need to evolve rapidly to keep up. How the Government of Canada collects, manages, and governs data—and how it accesses and shares data with other governments, sectors, and Canadians—must change.
- Through the power of data, public servants can fundamentally transform governments by changing the way they operate, make decisions, and deliver services.

Following consultations with all federal departments and agencies, this reportprovides a roadmap for more strategic use of data. The recommendations are structured around four themes: stronger governance, improved data literacy, and skills, enabling infrastructure and legislation, and more focused treatment of data as a valuable asset. The goal is to set a foundation so that the Government of Canada creates more value for Canadians from the data we hold.

Departments and agencies struggle with the same issues:

TABLE 3 Issues for departments and agencies

"Absence of horizontal governance for strategic direction on data issues"	"Lack of data literacy and cultural reticence to break silos"
"Lack of adequate digital infrastructure and a complex rules framework"	"Challenge of acquiring, governing and managing large volumes of disparate data"

The Data Strategy Framework for the Federal Public Service promotes six guiding principles for its whole-of-government approach to creating, protecting, using, managing, and sharing data as a strategic asset, enabling informed decisions that lead to better outcomes and services for Canadians: 1/ Client-centered; 2/ Trusted; 3/ Agile; 4/ Open; 5/ Enabling; 6/ Purposeful.

The list of desired outcomes for citizens, businesses, and governments includes (1) improved services, (2) greater public value from data, (3) greater usability and availability of data, (4) protection of individuals' information and privacy by design, (5) trusted and sound governance of data, which are treated as a valuable and strategic asset, (6) increased evidence-informed decision-making, (7) better reporting on results, and (8) increased intra and inter-governmental collaboration.

Since the 2018 launch of the Data Strategy Roadmap for the Federal Public Service, the Government of Canada has enacted in April 2019 the "Directive on Automated Decision-Making," which includes a comprehensive algorithmic impact assessment methodology for government agencies.

The Canadian algorithmic impact assessment guidance helps agencies fill out the assessment questionnaire. The questions take into account the scale and scope of the algorithmic system. Systems with limited impacts result in lower scores than those with broad effects. Similarly, expert systems where variables, weights, and processes are

known are rated lower than machine learning systems where all three of those factors may be unknown.

The assessment system is purposefully left vague so that it engages a broad group of public agencies, civil society, and commercial actors to map out algorithmic impact collaboratively. The final cumulative score classifies the algorithmic system into four levels (**Level I**: Little to no impact. Impacts will often be reversible and brief, **Level II**: Moderate impacts. Impacts are likely reversible and short-term, **Level III**: High impacts. Impacts can be challenging to reverse and are ongoing, **Level IV**: Very high impacts. Impacts are irreversible and are perpetual) based on its impact on (1) the rights of individuals or communities, (2) the health or wellbeing of individuals or communities, (3) the economic interests of individuals, entities, or communities, and (4) the ongoing sustainability of an ecosystem.

This strategy is committed to (1) improving transparency and openness, (2) continuing the development of innovative methods to preserve privacy, confidentiality, and security, (3) increasing access to data and microdata to create information that drives innovation, inclusion, and drives insights, (4) increasing data literacy and statistical capacity building, and (5) leading and fostering the strengthening of the national statistical system.

In May 2019, the federal government announced a new Digital Charter, a set of cross-cutting principles that will guide reforms to crucial legislation such as the Personal Information Protection and Electronic Documents Act, the Privacy Act, the Competition Act, and the Statistics Act.

These policy developments are most relevant to CIRANO's mission and ongoing applied research priorities as the economic and societal impacts of public policies, innovation, and digital transformation. Digitalization is now the key to building economic and societal resilience and exercising global influence. Digital technology can facilitate inclusion and access to public services in Canada around the world.

As recognized in the 2018 report to the Clerk of the Privy Council: "Governments need to evolve rapidly to keep up. How the Government of Canada collects, manages, and governs data—and how it accesses and shares data with other governments, sectors and Canadians—must change."

This assessment was reinforced by the auditor general report published the same year:

> *"The culture has to change! The government is at a crossroads. The government has a choice. It can either perpetuate the current culture and its problems—including the incomprehensible failures—or it can change that culture and reap the benefits of programs that work for people. My short description is that the culture has created an obedient public service that fears mistakes and risks. Its ability to convey hard truths has eroded, as has the willingness of senior levels—including ministers—to hear hard truths." (Government of Canada 2018b).*

The Ottawa-based Institute on Governance (IOG) held a series of four "Digital Governance Webinar Series" (Institute on Governance 2021) from September to November 2020. These consultations are rich in insights on the state of play in the federal government in this critical area of public service transformation and offer sobering perspectives on challenges ahead of us. Key takeaways from these experts' discussions can be summarised as follows:

- Digital is no longer just an "IT thing."
- User-centred design and agile is where we should be going, however…

- …our ways of working in the public service have not caught up.
- Budgeting, project gating, procurement, and HR are the real barriers.
- The rise of social media and other digital tools opens new possibilities and raises "signal to noise" problems.
- A deep sense of transformation fatigue.

4.4 | Data interoperability and data sharing

The consensus of the studies and policy papers surveyed for this report confirms that interoperability data sharing will enhance supply chain visibility and building capabilities and enable synchronized operation planning for a responsive resilient, secure, safe, and multimodal transport ecosystem. New models of public-private data-sharing partnerships are considered essential.

Data sharing is an essential driver for efficiency, simplification, lowering costs, and better resources and existing infrastructures. It creates new business opportunities and rapidly transforms how supply chains and intermodal transportation systems are organized and managed. Early adopters gain a solid competitive advantage over their followers: Those organizations that implement the new technology are likely to perform better than their hesitant peers (Bughin et al. 2018). Four critical takeaways for proof are offered:

- 80% of extensive AI adopters have better financial performance. Most (71%) extensive AI adopters expected a 10% increase in revenue.
- AI is not taking all the jobs. Despite fears to the contrary, companies who extensively adopted AI technologies reported increasing their headcount, with opportunities for "new collar" jobs and more cross-functional teams.
- Advanced AI adopters have an advantage in hiring. The report cautions that those hesitant or resistant to AI will be less attractive to qualified talent, as lower productivity without the technology will lower the wages they can offer. Conversely, advanced adopters of AI and automation will have a distinct advantage. In addition to attracting talented individuals and offering better wages, they will also have freedom of choice when hiring.
- The time to adopt is now. As the report says, "The pattern of significant growth and revenue gains going to firms at the forefront of adoption looks set to continue. Their ability to reinvest these gains and pull even further ahead of competitors may create an insurmountable advantage and increases the importance of all companies to consider how automation and AI could affect their businesses."

The magnitude of Canada's economic recovery challenge requires a systemic response, at the centre of which is the transformation of our governance, operating, and collaborative models. It forces us to:

- Mobilize public and private resources and multidisciplinary scientific expertise necessary to develop and implement the envisaged recovery plan.
- Reinvent our institutions' functioning and adopt a new conception of how we think and manage public and private organizations, including the intergovernmental system's management.
- Adopt an integrated and coherent response that must be agile and results-driven.

4.5 | Globalization and protectionism

The Canadian supply chain is a critical component of the Canadian economy, enabling the movement of $1 trillion worth of goods, generating $66 billion in GDP, and employing more than 878,000 people (excluding truck drivers) in Canada. In 2015, $1 trillion worth of goods were carried by Canadian carriers and $525 billion worth of exports (SCMA 2016).

McKinsey Global Institute analyzed 23 industry value chains spanning 43 countries to understand how trade, production, and participation changed from 1995 to 2017 (Lund et al. 2019). It noted that globalization reached a turning point in the mid-2000s. Although trade tensions dominate the headlines, deeper changes in the nature of globalization have gone largely unnoticed, although the Great Recession obscured these changes. Key findings from that comprehensive analysis are highlighted here:

- First, goods-producing value chains have become less trade-intensive. Output and trade continue to grow in absolute terms, but a smaller share of the goods rolling off the world's assembly lines is now traded across borders. Between 2007 and 2017, exports declined from 28.1 to 22.5 percent of gross output in goods-producing value chains.
- Second, cross-border services are growing more than 60 percent faster than the trade in goods, and they generate far more economic value than traditional trade statistics capture. We assess three uncounted aspects {value-added services contribute to exported goods, the intangibles companies send to foreign affiliates, and free digital services made available to global users). National statistics attribute 23 percent of all trade to services, but these three channels would increase their share to more than half.
- Third, less than 20 percent of goods trade is based on labour-cost arbitrage, and in many value chains, that share has been declining over the last decade.
- The fourth and related shift is that global value chains are becoming more knowledge-intensive and reliant on high-skill labour. Across all value chains, investment in intangible assets (such as R&D, brands, and I.P.) has more than doubled as a share of revenue, from 5.5 to 13.1 percent, since 2000.
- Finally, goods-producing value chains (particularly automotive and computers and electronics) are becoming more regionally concentrated, especially within Asia and Europe. Companies are increasingly establishing production in proximity to demand.

There are fundamental questions about whether trade activities will return to normal or whether some of the global production arrangements will be recast in the light of the COVID-19 experience.

After decades of expanding global value chains, some rethinking of these geographically dispersed production arrangements was already underway after the 2009 global recession.

> *"The average length of global supply chains was shortened by about 50 kilometres per year between 2012 and 2016. US President Donald Trump's trade war with China in the past three years has put additional strain on global value chains, with firms struggling to circumvent the heightened trade barriers between the world's two largest economies. The virus pandemic will only heighten concerns about the vulnerability of our economy to shocks that occur far from our borders and the role that global value chains play therein" (Gangnes and Van Assche 2020).*

Internal trade is an essential component of business growth in Canada, particularly for small and medium-sized enterprises. Over the years, interprovincial trade in goods and services has grown steadily and in 2017 reached more than $406 billion. Significant progress has been made in recent years in trade liberalization in Canada. Canada's domestic goods market's full liberalization can increase GDP per capita by about 4% (Alvarez, Krznar, and Tombe 2019).

Federal, provincial, and territorial governments should reduce internal trade barriers as their shared priority with much at stake. Internal trade barriers are a longstanding issue. Nothing short of a sustained and concerted collective effort will be necessary to break down barriers that impede Canadian businesses from competing on a level playing field and scaling up. Easier access to the entire Canadian market could also attract more investment to Canada. A "coalition of the willing" could be one way to accelerate progress, as suggested by the IMF paper.

The pandemic accelerates the ongoing disruptions in global (and North American) supply chains. In response, the envisaged recovery plan cannot have the desired impact without creating such a united internal market.

The effects of the COVID-19 crisis on international trade provides timely insights and guidance are highlighted here (OECD 2020):

- At the international level, diversified production is often a source of resilience and adjustment for businesses in an unfavourable environment. At the same time, experience in the agri-food sector has shown that self-sufficiency in supply is not the same as security of supply.
- It will also require businesses and governments to rethink how best to ensure supply chains' resilience. This will require a better understanding of key supply chains' strengths and vulnerabilities in the current crisis and a re-analysis of resilience toolkits considering this.
- For corporate strategies, this may mean a re-examination, for example, of the structure of companies on a global scale, including redundancy capacity and inventories.
- Governments will need to consider the trade and investment policy environment that can best support resilience, for example, the availability of digital infrastructure to reduce productivity losses during pandemics or improved transition facilitation practices to minimize the potential for disruption of face-to-face processes.
- Governments may also need to consider special arrangements for specific supply chains for strategic goods such as medical equipment; however, this does not necessarily have to be equated with production repatriation.
- For masks, for example, it would be very costly for each country to develop a production capacity corresponding to the current crisis demand and encompassing the entire value chain; an alternative, efficient, and more cost-effective solution may involve the development of strategic stocks of upstream agreements with companies allowing rapid conversion of assembly lines in the event of a crisis.

As is the case for all sectors of the economy and society, Covid-19 accelerates the more regionalized economies' pre-existing trend. Since the 2008 financial crisis, the share of intra-regional trade in goods has increased by close to 4 percentage points (Raza et al. 2021). This "regionalization of globalization" directly relates to the Saint-Lawrence Great Lakes Trade Corridor and its critical role in the North American economy.

The COVID-19 pandemic has already had and will continue to have far-reaching effects on international trade, and given its heavy reliance on trade, the Canadian economy.

4.6 | Climate Change

The Senate Committee report "Decarbonizing Transportation in Canada" tabled in June 2017, states for its part that greenhouse gas (GHG) emissions from the transportation sector accounted for almost a quarter (23%) of all GHGs in the country, second only to the oil and gas sector as the largest source of GHG emissions in Canada. Passenger and freight vehicles are responsible for most transportation emissions, a function of the need to move people and goods throughout Canada's vast geography. This report highlights opportunities to reduce transportation-related GHG emissions through new technologies, regulatory measures, international standards, alternative fuels, targeted climate policies, and investment into intermodal transportation corridors and public transit systems.

According to the latest figures from Environment and Climate Change Canada, the transportation sector was responsible for 25 percent of greenhouse gas (GHG) emissions in Canada in 2019. Light-duty vehicles – the cars, vans, and light-duty trucks we drive - are responsible for almost half of that total (Government of Canada 2021).

The OECD economic survey of Canada 2021 (OECD 2021a) recommends following through with the current plan to accelerate the increases in carbon pricing and taxation through 2030 while protecting the poorest from the impact on their living standards and to make greater use of taxation and charges to tackle environmental externalities as well as to expedite the removal of non-tariff barriers to internal trade.

The intermodal transportation system and the supply chains are a key source of GHG emissions in Canada. They can also be a game-changer in the fight against climate change (Burchardt et al. 2021), according to the most recent report jointly published by the World Economic Forum (WEF) and Boston Consulting Group (BCG):

> *"Eight supply chains account for more than 50% of global emissions. Food, construction, fashion, fast-moving consumer goods, electronics, automotive, professional services, and freight account for more than half of all global greenhouse gas emissions."*

According to this report, in most supply chains, the costs of getting to net-zero (the state in which as much carbon is absorbed as is released into the atmosphere) are surprisingly low. Even full decarbonization would result in end consumer price increases of only 1% to 4% in the medium term. However, this joint WEF-BCG points out a key challenge in decarbonizing supply chains: access to the data needed to set clear targets and standards to which stakeholders must adhere. Engaging an often fragmented supplier landscape is challenging – especially when emissions are "buried" deep in the supply chain or when addressing them might require collective action at the industry level.

In May 2017, along with Natural Resources Canada, Transport Canada released a report on climate risks and adaptation practices (Palko and Lemmen 2017). It includes the current knowledge about climate risks to our transportation sector and how to adapt. It is the first of its kind in Canada, focused solely on transportation. It underscores that the effects of a changing climate and extreme weather present both risks and opportunities to transportation infrastructure and operations. Some of its high-level conclusions are summarized here:

- "Transportation infrastructure, essential to Canada's domestic and international trade, is vulnerable to damage and disruptions from a changing climate and extreme weather. This can pose risks to other sectors of the economy. Studies are underway to understand these vulnerabilities better, and adaptive practices are being undertaken to reduce future impacts. Regional chapters provide further details on initiatives related to the GLSLTC…"

- "A changing climate is expected to result in some opportunities for Canadian transportation. Potential benefits include longer marine navigation and construction seasons, reduced winter maintenance, greater operating efficiency for rail, and improved fuel efficiency for all modes. Melting sea ice is also slowly opening up Arctic waters to new navigation routes; however, the increased mobility of summer sea ice and increased coastal erosion and storm surge flooding present ongoing difficulties for shipping, exploration, and associated coastal infrastructure.
- Reactive approaches to managing climate risks (e.g., responding to past impacts or events) remain common in Canada's transportation sector. At the same time, examples can be found of actions being taken in anticipation of future climate conditions. Many owners and operators, both public and private, have adapted their operations based on investigations and lessons learned from past weather-related events. Transportation decision-makers are also more frequently engaging in proactive planning.
- Transportation decision-makers are increasingly adopting a risk management approach to reduce climate risks to their infrastructure and operations. A variety of specific practices are being used to enhance the climate resilience of transportation systems, including integration of climate considerations into organizational planning, policy and design changes, risk and vulnerability assessments, structural and physical adaptations, smart technologies, and operational and maintenance changes" (p.13).

Transport Canada supports the development of other measures outlined in the Pan-Canadian Framework on Clean Growth and Climate Change (Government of Canada 2016), including the federal carbon pricing benchmark; clean fuel standards as well as research and testing on clean transportation technologies for all modes of transportation.

In partnership with Innovation, Science, and Economic Development, Transport Canada engages industry and stakeholders to develop a Canada-wide strategy for zero-emission vehicles. A national advisory group of government and industry representatives, academics, consumers, and other organizations supports this commitment.

4.7 | Stakeholders' expectations

The magnitude of the challenge also underscores the need to reinvent the governance and operating models of Canada's citizen-centered intergovernmental system by instituting agility and simplified access to programs and services from different levels of government. Speed and effective collaborations are key factors of our competitiveness and our collective ability to emerge quickly from this major crisis and return to the path of new normalcy and, hopefully, sustained and growth.

Technology is an enabler of transformation; it is not an end. Innovation is the key to the public sector's ability to deliver on its user-centric promise continuously. Citizen/user focus is often impeded by public sector culture, hierarchical organizational structures, and differing public sector priorities. However, innovation in the public sector is different from innovation in the private sector – it is not about filing patents; it is about the impact and requires continuous incremental change: it is key to the sustainability of government transformation.

Such a transformation requires:

- Visible leadership at a strategic level (sustained involvement of senior management supported by understanding and encouragement from political leadership
- Common goals for connected government – and common service standards

- Focus on the front end of public service delivery – achieve quick wins and visible improvements
- Break down intra-agency silos before starting to break down cross-agency silos
- Modernize legal framework in place and enact accordingly enabling regulations

4.8 | Key risks and trends

Unprecedented policy response and rapid progress in vaccine development have helped pull the global economy from a deep recession. Without these fiscal and monetary measures, the global contraction last year would have been three times worse—this could have been another Great Depression.

There are increasing challenges to an open global economy, making it harder for Canada to defend its values and interests. Economic recovery is expected to be uneven across sectors and demographic groups, likely to come in waves. The risks of disruptions are on the rise, and as pointed out by the IMF managing director on April 7, 2021:

> *"Economic fortunes are diverging dangerously. A small number of advanced and emerging market economies, led by the U.S. and China, are powering ahead weaker and poorer countries are falling behind in this multi-speed recovery…We also face extremely high uncertainty, especially over the impact of new virus strains and potential shifts in financial conditions. And there is the risk of further economic scarring from job losses, learning losses, bankruptcies, extreme poverty, and hunger." (Georgieva 2021)*

As a result of COVID-19 and the global response that it prompted, we find ourselves having to accept a new normal, both in Canada and abroad: it changed geopolitical dynamics, digitization, and climate change and has accelerated socio-economic trends — a rising inequality, shifting consumer demands, and disruptions to our trade and supply.

If we look to GDP as an indicator, a return to pre-COVID-19 levels is unlikely before 2022. COVID-19 has had a disproportionate impact on sectors partly due to the effects of containment measures and the adaptability of their business operations.

Canada can build back better with a stronger economy and a faster growth rate than we saw before the onset of COVID-19. We see this crisis as an opportunity to reimagine our position on the global stage as an innovation leader, but we need to move quickly. Our efforts need to focus not just on recovering from the devastating economic impact of the pandemic but also on Canada's future. We need to build a digital, sustainable, and innovative economy for all Canadians. In particular, one that is stronger than our pre-COVID-19 economy.

It is time to increase our competitiveness, innovation, and productivity by investing in foundational areas to build synergies across economic sectors. Take our digital footprint and investments in e-commerce and information and communications technology (ICT), for example. We believe that investments in value-added manufacturing and processing, sustainable clean technologies, and digital connectivity are key to ensuring prosperity and jobs while enhancing the Canadian economy's overall performance.

The world's top risk is the "prolonged recession of the global economy" as the most feared risk of COVID-19 (World Economic Forum 2021). The following list summarizes these key risks and trends:

- The virus and vaccine trajectory: More than twelve months into the pandemic, large-scale vaccination campaigns, and the apparition of variants, the public health situation is contrasted among countries and remains uncertain.
- The future of remote work: Although remote work arrangements provided continuity for people having internet access and whose jobs do not require physical presence, the longer-term impact of remote work on workforces and productivity is unclear.
- Growing income inequality: More data is emerging about the deeply asymmetric impact the pandemic has had on different groups, exacerbating historical disparities by race, gender, skills, and income, as well as across high- and low-income countries.
- The digital economy's acceleration in 2020 moved a large proportion of work, consumption, and social life online.
- Bigger government: Managing the pandemic has established a larger presence for the state in the global economy.
- Deglobalization: In the highly uncertain trade environment caused by the pandemic, the first set of COVID-19 lockdowns led to a collapse in manufacturing and services trade in the first quarter of 2020, which pushed policymakers and businesses to rethink their place in global value chains. As trade volumes rise again, patterns are likely to adjust to a new long-term trade structure.

TABLE 4 Challenges and key trends for Canada identified by the Industry Strategy Council

Challenges	Key trends
Insufficient investment in trade, innovation & digital infrastructure	Changing global dynamics: growing divergence in interests between key economies (e.g. China and USA) and rising protectionism due to COVID
Fragmented domestic market & inefficient regulations: lack of agility and interprovincial barriers to the movement of people, goods, and investment	Technology accelerating industry disruption: the increasing importance of the intangible economy (e.g. data, software)
Low trade diversification: over-reliance on US trade despite agreements with many other countries	Rising income inequality, workforce vulnerability, and social unrest: >70% of the global population is facing growing income inequality, and public awareness of systemic racism is on the rise
Lack of value-added processing: reliance on exports of commodities with insufficient high-value transformation	Climate change is a global challenge: Capital markets, investment, and consumer preference have shifted to decarbonization and the need for an economy that is resilient to climate shocks
Challenges to scaling and commercializing IP prevent Canadian firms from growing into large, global-leading organizations	Major disruptions to trade & supply chains: COVID has highlighted a need for increased resiliency, efficiency, and diversification of supply chains
A fragmented health care system lacks interoperability and adds complexity to crisis management and rising mental health concerns exacerbated by COVID-19	

Challenges	Key trends
Insufficient wealth creation: limited, leading global Canadian firms and businesses to support the economy and nurture domestic talent	

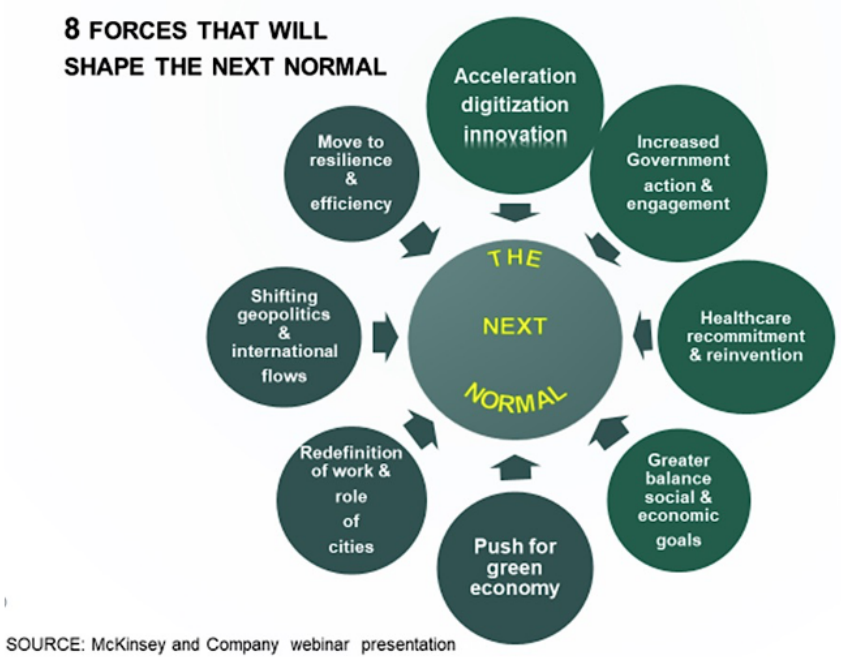


FIGURE 6 Forces that will shape the next normal. Source: Sneader, K. (2020, décembre 9). The future of business: 2021 and beyond.

5 | DATA IMPORTANCE AND ISSUES: INTERMODAL TRANSPORTATION SUPPLY CHAINS IN CANADA AND NORTH AMERICA

Let us turn our attention to the data dimension in a more granular way.

5.1 | The Great Lakes - St. Lawrence Seaway Trade Corridor

We will first present the broad challenges across transportation modes.

5.1.1 | Broad challenges for each mode of transportation along with the SC in the Corridor

Supply chains supporting trade are increasingly long and complex. The exchanged products have been manufactured from components and raw materials imported from several countries on different continents. Furthermore, these goods are distributed and made more easily accessible in new markets internationally (Roy 2015).

The World Bank's Logistics Performance Index (LPI) assesses the competitiveness of a country's logistics system. This indicator, ranging from 1 (worst performance) to 5 (best performance), is based on a survey sent to roughly a thousand managers and specialists working for freight forwarders and international courier companies and is established using responses concerning the following criteria: competence and quality of logistics services; the frequency with which shipments reach consignee within scheduled or expected time; quality of trade and transport-related infrastructure; ability to track and trace consignments; efficiency of customs clearance process; ease of arranging competitively priced shipments. According to the most recent LPI rate, Canada was ranked 14th globally with a score of 3.90 in 2018[3].

This leads to say that Canada's overall transportation and logistics systems perform relatively well compared with those in other countries. However, efforts still have to be made in several parts of the country's supply chain. Areas of improvement in the Canadian SC include domestic road congestion, container port competitiveness, rail capacity, air cargo capacity, competitiveness, and airport landing fees (Roy 2017).

We provide a short overview of the main features and broad challenges faced by each SC's transportation modes in the Great Lakes - St. Lawrence Seaway Corridor. It provides a particular focus on works realized or recommended by university researchers belonging to the CIRANO community or those who have been consulted to prepare this report.

Air freight

Airfreight represents the fastest but also the most expensive mode of transportation. It is mainly used for urgent deliveries and the transport of perishable and high-value products such as pharmaceuticals, aeronautical products, fresh food, and newspapers and magazines. These products can be carried in the baggage compartments of passenger aircraft or all-cargo aircraft. Passenger aircraft transport nearly 60% of all air cargo (Roy 2015).

Compared with major US airports, Canadian airports face competitiveness issues in the North American landscape regarding handling freight. This is in part because air freight capacity on the continent is concentrated in Memphis (FedEx) and Louisville (UPS) for integrators, and in Los Angeles, New York, and Chicago for international commercial airlines, leading to an air freight cost disadvantage for Montreal, and Toronto to a lesser extent. Concerning western

[3] https://data.worldbank.org/indicator/LP.LPI.OVRL.XQ?end=2018&locations=CA&most_recent_value_desc=true&start=2007&view=chart

cities, Vancouver has lower air freight costs for outbound cargo to France, Germany, Italy, and Singapore than Los Angeles and Seattle, but has less capacity compared with those cities. As for inbound cargo from Europe and Japan, Los Angeles is the most competitive option compared with Vancouver and Seattle. A second challenge concerns air cargo capacity. The absence of regular air cargo freighter services (other than the courier services provided by integrators such as FedEx and UPS) in most Canadian airports causes some traded items leaving Canada to non-US final destinations to be transferred by air, rail, or road to US air cargo facilities; a phenomenon referred to as "international leakage." For instance, Montreal's aerospace cluster has no direct flights from suppliers or customers, constraining aerospace shippers operating in the Montreal area to truck oversized components for passenger planes to Toronto, New York, and Chicago airports for overseas exports (Roy 2017).

Marine transportation

Marine transportation is the second-most-used mode for Canadian trade, enabling high capacity at a low cost. Canadian ports are as a whole well equipped for bulk products, including petroleum products, grains, food products, passenger vehicles, nonferrous products, coal, machinery and equipment, wood products, iron ore, and potash (Roy 2017). However, some container ports, such as Montreal, located on the relatively shallow Saint Lawrence River, are pressured by the increasing size of incoming container vessels.

Trade routes are dynamic and changing: shipping lines have adapted their vessels to the continued international trade growth and to recent international canal expansions, which poses increasing challenges to the ports infrastructures in their ability to handle growing cargo volumes but also provide added landside storage capacity for increased peak loads, deeper approach channels and berths, larger turning basins, along with bigger and more productive cargo-handling equipment (Association of Canadian Port Authorities 2018).

Some facts and challenges can be mentioned here about the port of Montreal:

- The Port of Montreal's capacity is adequate to handle bulk, liquid, and solid cargo, apart from petroleum products for which the infrastructure must be improved.
- The Port of Montreal has its rail infrastructure facilitating intermodal exchanges with CN, and CP is advantageous. However, access to the port for trucks is quite tricky. They must use Notre-Dame Street, which is often congested, an improvement that necessitates better communication between all stakeholders, including the City of Montreal and the Quebec government.
- Montreal provides the shortest route between Europe and the Mediterranean on the one hand and North America on the other, with waiting times comparing favourably with U.S. standards. However, winter conditions can cause some reliability challenges for incoming containers.
- Ocean vessels that dock at the Port of Montreal do not go elsewhere; they are loaded or unloaded completely. Montreal represents the only inland port of call in North America on trans-Atlantic services, making it a unique market for containerized traffic (Comtois and Slack 2015).
- Seasonal variations of water levels in the Great Lakes - St. Lawrence system affect navigation and the competitiveness of ocean carriers in the Port of Montreal. With no major tributaries, the water depths of the Great Lakes depend on precipitation levels. The relationship between a vessel's carrying capacity and water depth provides a benchmark for estimating the economic impact of water level changes. A variation of one centimetre in water level at the Port of Montreal has an estimated economic impact of $1,122.73 per vessel (Comtois and Slack 2015).

Climate change provides additional challenges due to its effects on river depth and other environmental issues, coupled with growing concerns from an increasingly informed population.

Rail freight

Rail has low operating costs and high carrying capacity and hence is the preferred mode of transportation for high volume, low-value commodities such as raw materials that must travel long distances. It is the only mode of transportation that must bear the full cost of developing and maintaining its infrastructure. In this regard, the Canadian rail industry has often been criticized in recent years for not investing sufficiently in its infrastructure and capacity to provide the level of service expected by its customers (Roy 2015).

Regarding intermodal trade, high volume rail corridors in urban areas conflict with passenger commuter rail traffic on the one hand and with surface road traffic at at-grade railroad crossings. According to (Dablanc et al. 2013), "the main trade node city strategy to address these problems is the capital investment to increase rail capacity and eliminate at-grade rail crossings. The major challenge to capital investment strategies is the lack of an obvious funding source. Railroads have little incentive to incur costs to solve road transport problems and are typically unwilling to pay. Local jurisdictions have no authority to force railroads to incur these costs. They also have little incentive to pay, as they view the rail traffic as a national responsibility." (p.12) These observations made for the US case can also be applied to the Canadian context.

Lastly, since the Lac-Mégantic accident and other derailments involving petroleum products, safety has become another priority issue in the North American rail transportation industry.

Roads and border crossing

Road transport remains the preferred mode for cross-border trade with the United States and some Latin American countries, making fluidity at border crossings a major performance factor. The three busiest border crossings between Canada and the US are Ontario, Windsor, Fort Erie, and Sarnia. Wait times at two of the main border crossings in Ontario (Fort Erie and Sarnia) are satisfactory: less than twenty minutes, which does not represent a major bottleneck. The views of some trucking executives corroborate this conclusion. Additionally, the expected completion in 2024 of the new bridge across the Detroit River between Windsor and Detroit in the medium-term should ensure that delays at border crossings for road transport will remain under control. However, according to Roy (2015), continuing field studies by measuring wait times in Windsor or other border crossings such as Lacolle, Quebec, would be of valuable interest.

Other challenges for the Canadian trucking industry include the potential shortage of drivers as well as variations in energy costs: the trucking industry is by far the largest consumer of energy among all modes of transportation, accounting for 85% of the transport sector's energy use (Roy 2017), and must invest in new engines and technologies to lessen its energy use and its environmental impact.

Compared with other countries, Canada's transportation infrastructure and logistics perform relatively well, but there is still room for improvement in some areas. A few recommendations are worth mentioning (Roy 2017):

- "A logistics cluster strategy and development plan should be an integral part of the [Ontario-Quebec Continental] gateway program.
- Plan continentally: There is a solid case to be made for adopting a continental, North American approach, rather

than simply focusing on Canada's international border, in planning transportation systems and infrastructure, as well as a security perimeter.

• Relieve domestic road congestion: Through its infrastructure programs, the Federal Government should assist provincial and municipal governments to repair roads and improve the fluidity of truck movements. Congestion at border crossings may no longer be a major issue, but road congestion in large urban areas is a big concern for shippers across the country. Canadian exports travel long distances by truck before reaching exit points such as ports and border crossings. Road congestion adds to the cost of imports and exports and negatively affects the competitiveness of all industries that move products across major urban areas" (p. 458-459).

5.1.2 | Transportation and trade data challenges

Access and interoperability issues

The literature review on intermodal transport data often emphasizes interoperability issues between the various modes of transportation caused by a lack of standardization in data collection formats, communications protocols, and data semantics. Becha et al. (2020) carried out a study on these issues within the framework of the DTLF project outlined in section 5.4. The authors point out that although a significant amount of valuable data is being collected through various government programs, public authorities may still face challenges in accessing and using these data. Besides, the needs and priorities between the industry and the public authorities are also misaligned, the first to focus on their performance and profitability. At the same time, the latter will generally adopt a broader perspective to address SC efficiency or safety improvement goals.

The study also mentions issues of data semantic interoperability along the logistic chain: the use of different standards for identification and tracking between the various transportation modes complicates the exchange and transmission of all the pertinent information to the varied stakeholders in an intermodal transaction. Considering the potential provided by IoT data for the improvement of the door-to-door logistic chains, solutions must be found to enhance the physical connectivity of the devices among the different IT systems. Efficient interoperability within end-to-end SC will only be achieved by adopting internationally agreed and recognized data communications standards exchanged between the transport operators and their stakeholders, regardless of the mode of transport. These observations are made in the European context; in our opinion, they also apply to the Canadian SC.

Several initiatives have been set up for better intermodal data interoperability, including at the organization level with GS1[4] and UN/CEFACT[5], which provides recommendations on electronic business standards and trade facilitation. Although UN/CEFACT released reference data models for international SC and multimodal transport[6], there is still room for improvement in the adoption of Tracking and Tracing in a multimodal approach within the industry (Becha et al. 2020). "Federative" data platform initiatives are now in an implementation phase: business operations data are not stored within the network itself. In Europe, several projects receive funding from the European Commission like PEPPOL[7] and FENIX[8] Network and the FEDeRATED Network of platforms[9].

[4] https://gs1ca.org/

[5] https://unece.org/trade/uncefact

[6] https://unece.org/trade/uncefact/mainstandards

[7] https://peppol.eu/what-is-peppol/

[8] https://fenix-network.eu/

[9] http://www.federatedplatforms.eu/

These networks of platforms follow a "four-corner model," whereby two organizations can transmit or exchange data (using agreed technical protocols) from two different access points.

The willingness of stakeholders to share data

Another issue concerns the complexity of sharing transportation data, especially from private businesses, which collect data for commercial use or meet mandated regulatory requirements.

The analysis supported by consultations with HC stakeholders on data issues for the Australian freight sector presents findings that can also be applied to the Canadian context (Christensen, Kasparian, and Leow 2019). They observe that although the freight industry, in principle, recognizes the necessity of sharing operational data for the overall improvement of the SC efficiency and productivity, firms turn out to be reluctant to commit themselves or undertake initiatives in this sense. The main barrier impeding these firms from sharing their data is their concern that they could lose competitive advantage, give their competitors detailed insights into their operations, and communicate commercially sensitive data with third parties. According to the authors, fostering access to privately-owned data necessitates:

- an emphasis on the potential benefits to companies to return for their effort to share their data, as well as
- an assurance that the collected and published data is sufficiently transparent to enable benchmarking, and aggregated enough to accommodate confidentiality and commercial issues.

Other data-related challenges

Other general data-related challenges in the freight transportation sector include (Christensen, Kasparian, and Leow 2019):

- "The absence of a systematic data collection approach, a lack of timeliness in terms of data delivery and dissemination, fragmented datasets that do not enable end-to-end supply chain visibility, and a lack of traction in previous initiatives on establishing some sort of data centre." (p.8)
- "The national data surveys are costly and follow time-consuming cleansing and analyzing processes. As a result, there is a long-time lag before data can be released for use by the public.
- In some cases, the lack of statistically suitable sample sizes leads to a suspension of data collection. Hence, critical information is missing in some aspects of the freight task datasets, including seasonal variations, activity-based, and commodity-based information." (p.19)

Our consultations with university researchers and experts from Transport Canada provided additional insights on the current situation with data applied explicitly to the St-Lawrence Seaway corridor. They are presented and classified below.

Data challenges at Transport Canada (consultations)

- The availability of Canadian transport data is diminishing for stakeholders, and inefficiencies are created by:

(1) information asymmetry between users and carriers,

(2) lack of access to information on supply chains, modes, overall performance, and
(3) inaccessibility of confidential operational and strategic carrier data.

- Significant availability of data for the air and rail sectors (federally regulated modes of transport and voluntary transmission from industry players): traffic, productivity, financial performance, movements of hazardous materials, transport performance indicators, freight, and passenger movements (rail and air).
- Limited data availability for the marine and road sectors (sparse data, jurisdictional issues). There are numerous gaps for air data regarding minor routes and the North, cargo, and financial information on carriers and airports.
- Except for grains, containers, and potash passing through Vancouver, intermodal traceability from origin to destination should be improved.
- Difficulty accessing passenger transportation data (privacy issues on carrier data); no passenger flow data for regional routes (need to consult airports) and obtaining data on air cargo in the Montreal area.
- There is a lack of data on road pricing, little data on traffic and vehicle types, and challenges in accessing truck GPS data.
- Limited capacity for new data collection methodologies (real-time, big data, and others).
- Issues of collaboration among departments in data collection were mentioned (isolated and uncoordinated operations).
- Transport Canada organizes formal forums (Commodity Supply Chain Tables) to discuss transportation issues with other industry stakeholders. Databases interoperability needs to be further implemented between other government departments, provinces, and territories.
- There is no legal requirement for businesses to respond to Statistics Canada surveys; firms across the country are reluctant to disclose their data.
- The study of the last segment of SC in urban areas is critical. Still, there is an information asymmetry and no data interoperability between Transport Canada, the provinces, and municipalities. For instance, Canada's large cities have expertise on urban transportation issues, but models are developed locally, creating a lack of comparability among these models.
- There are problems with updating and insufficient standardization of the data needed for urban mobility studies. Besides, outdated and non-updated territory data limit calculation possibilities for research. These data include the position of housing units, presence of businesses, street widths, sidewalk coding, loading docks, number of lanes, traffic speeds displayed…

5.1.3 | Urban freight transport and last-mile strategies

Urban freight transport surveys

Urban freight is an integral part of the SC and must also be considered in an end-to-end analysis. Compared with the other modes of transportation, few publications are dedicated to surveys on urban freight transport and in-depth methodologies on this topic. Furthermore, to our knowledge, fewer are explicitly applied to urban spaces of the Great Lakes - St. Lawrence Seaway Corridor, which opens many research opportunities on this topic in our region. This section is based on two references recommended to us by two CIRANO researchers we consulted while drafting this report. Even though these studies do not focus specifically on the Corridor, they provide valuable insights into the methodologies used in this research area and its complexity.

Two types of urban freight surveys exist (Patier and Routhier 2010):

1/ Surveys made with data collected for traffic measurement purposes but not oriented towards knowledge of the formation of urban freight flows. Vehicles are taken as the statistical unit and are observed on the road or by the company using it to get information on the use and traffic of these vehicles. However, these surveys neither provide precise details about the vehicles' routes nor the dynamics of the flows observed.

2/ Specific surveys whose primary objective is to describe urban freight flows and explain why and how these flows occur.

The authors also report on the complexity of conducting logistics studies in urban areas:

- The transport of goods in cities is carried out by various operators, using different vehicle types. The goods delivered can be of different weight, volume, and packaging, with frequencies depending on the requirements of the relevant logistics chains.
- Externalities (e.g., congestion, energy consumption, and environmental impacts) cannot be assessed solely with origin/destination flows. Goods transported between two areas can be delivered directly or on complex tours involving several deliveries.
- Data on the types of vehicles used and national statistical agencies do not typically collect their routes, the products transported (packaging, weight, volume), or delivery frequency. They must be obtained from the transport operators and drivers.

Last-mile strategies

The last mile refers to the final route of a shipment to its end-receiver: a business, a facility, or a residence. Several last-mile strategies can be explored to optimize urban freight and its impacts, including (Dablanc et al. 2013):

- Labelling and certification programs promoting the use of cleaner vehicles/fuels; or operations during less congested times of the day and allow access to loading facilities or extended delivery hours. Such incentives may increase trust and foster enhanced collaboration between industry and government.
- Traffic and parking regulations restricting truck access or limiting truck deliveries to specific days of the week. Nevertheless, according to the authors, the experience shows that these tools have somewhat limited success: Truck parking restrictions may result in trucks double-parking, and traffic regulations concentrate traffic in shorter periods, generating more congestion.
- Consolidation programs seeking to combine pickups and deliveries of different shippers or different receivers for more efficient routing of final deliveries. Examples are pickup centers for online purchases and shared logistics spaces, where other shippers use an in-town facility to consolidate loads before the last deliveries.
- Off-hours deliveries to move truck activity out of the peak traffic periods to reduce congestion and emissions. Constraints may include legal requirements of hours of service, shift premium pay for drivers, and possible efficiency losses due to shipments spread across more hours of the day.
- Use of Intelligent Transport Systems for monitoring or managing urban freight, including technologies for providing real-time traffic information and comprehensive data on truck movements for enhanced analysis of urban freight problems. However, such data may be considered private by trucking companies and shippers. There are opportunities for research on better routing algorithms based on actual fleet movements in this field.

5.2 | Data Sharing: A Strategic Asset for Intermodal Transportation and Supply Chain Infrastructure

5.2.1 | Data sharing and innovation

When properly selected and used, data represent a valorization resource that can prove to be of significant benefit to SC operators, public authorities, and researchers. For data owners, the added value derived from an expert utilization of data can result in better access to innovation and decision-support tools and improved overall profitability of the transportation ecosystem. In turn, researchers and other experts have access to a precious field-generated resource for their work. Therefore, far from being a simple transfer of information, data sharing should be an opportunity to strengthen cooperation between the creators of the data and the experts (both from the government, the private sector, and the research community). They can analyze these data to create added value for improved SC efficiency.

A data platform may respond to several issues by providing all stakeholders in the transport and trade sectors with an interface for exchanging and pooling various data types coming from different systems. Data of different kinds that are sometimes left in silos and require time and resources to be exploited can be aggregated and valorized to benefit all stakeholders and the public. However, it is also fundamental to consider the relevance and quality of the data to be shared. A large amount of data does not mean that it will be helpful in decision-making or research.

Access to datasets can be done by downloading them from a cloud if this functionality is offered or through an API (Application Programming Interface). An API is a programming interface made available by a data provider that opens its data via a URL. In the case of data deposited on a cloud, the datasets must be deposited in a format or exchange standard that can be used. The design of a data exchange portal should ideally be easy to use, both for the programming expert and the data provider. A phase of adaptation to the tool may be necessary; user tutorials and training are usually welcome in this respect (Royer et al. 2020).

Data sharing is an essential driver of efficiency, simplification, lowering costs, and better resources and existing infrastructures. It enables enhanced SC visibility and building capabilities and synchronized operation planning for a responsive, secure, and multimodal transport ecosystem. In this regard, data sharing represents a crucial component for innovation, transforming the organization and management of SC and intermodal transportation systems.

Concluding recommendations on the need to reap the benefits of the use of information technology and data collection in Canada were made (Roy 2017):

- "Encourage the use of information technologies: Canada lags behind the competition — especially the United States — in adopting new information technologies for logistics and supply chain applications. Canada, therefore, should assist the use of intelligent transportation systems and new technologies to facilitate transportation, which could help alleviate the road congestion issue. The use of information technologies could also help lower the cost of complying with various government rules and customs regulations and facilitate international trade.
- "Improve data collection: Canada needs to collect more and better data on its trade flows. Specifically, Transport Canada should collect more data on the performance of ports, airports (including working with Statistics Canada to collect adequate air cargo data), bridges and other entry points. Canada's transportation, trade and supply chain performance — and by implication its broader economic performance — cannot be improved if it is not measured accurately." (p.459)

Canadian Port Authorities consider integrated information technology and advanced data management the "next frontier of port efficiency," referring to the numerous disruptive technologies enabled by data-sharing, such as blockchain applications currently being tested by Canadian port authorities (Association of Canadian Port Authorities 2018). They mention the case of Halifax Port Authority, which joined TradeLens[10], a digital global SC platform developed by Maersk and IBM and supported by a blockchain-focused digitization[11] solution. The platform's main objective is to connect stakeholders of the global SC ecosystem: It includes traders, freight forwarders, inland transportation, ports and terminals, ocean carriers, customs, and other government authorities— and allow secure and seamless sharing of real-time, usable SC information across all participants within a single collaboration IT system. With this participation in the platform, Halifax Port Authority expects to reduce costs, improve productivity, increase the speed of goods delivery, and enhance security and transparency in the SC[12].

Given the critical need for ports to keep up with the competition, a joint working group was recommended to establish between the Canada Port Authorities, Transport Canada, and the Canada Border Services Agency (Association of Canadian Port Authorities 2018). Its mandate would be as follows:

- the development of a digital road map with prioritized projects dedicated to SC efficiency (facilitation of appropriate data sharing across port authorities and SC stakeholders, more rapid clearance procedures from CBSA,
- the establishment by Transport Canada of a proper technology fund dedicated to identified prioritized projects) and support an industry-wide adoption of innovative technologies.
- Continuous long-term funding support for Transport Canada's Data Initiative by the Government is also crucial.

5.2.2 | Big data analytics and predictive analysis

New opportunities and challenges associated with big data refer to the start of a new industrial revolution (Warin et al. 2014). This discipline brings significant changes for governments, businesses, and organizations, enabling radical data collection and analysis transformations. New tools are developed to exploit structured data (i.e., data that can be coded or identified, for instance, spreadsheet data) and unstructured information (for example, text, audio, and video files). According to the authors, there are still new opportunities with big data.

According to a KPMG international survey with SC senior executives, the application of big data analytics should facilitate (1) the implementation of the right solutions to accurately analyze and interpret data, (2) the identification of the right risk indicators, and (3) a timely reaction to insights as they arise (Brunekreef and Pournader 2018).

AI-driven concepts have long been applied to the logistics sector as trucking, rail, and ocean freight were already tracked by satellite through telematics. However, these data were not utilized to their full capacity.

With big data, collected information can be exploited in a better way. Integrating all SC data, their analyses, identifying patterns, and gaining insight into each link in the SC are considered essential steps forward. Allowing insufficient resources to study the datasets available on critical SC operations could result in lost opportunities and unexpected disruptions of SC and an unsatisfactory customer experience (Freeman 2020).

Machine learning is "a predictive tool used to handle massive data and to approximate unknown models by very flexible

[10] https://www.tradelens.com/

[11] Gartner's glossary defines « digitization » as "the process of changing from analog to digital form, also known as digital enablement."

[12] https://www.portofhalifax.ca/halifax-port-authority-joins-digital-global-shipping-platform/

functional forms while controlling the risk of overfitting through regularization techniques. Thus, it is a powerful tool for data analysis that does not require much a priori knowledge about the structure of the data or the shape of the model" (Stevanovic 2021).

Coulombe et al. (2019) study the key features of machine learning modelling, which improve macroeconomic prediction. They show that compared with standard (linear) macro-econometric methods, machine learning models enable forecasting gains by capturing important nonlinearities associated with uncertainty and financial frictions. However, and despite the growing interest in this field, understanding the properties of machine learning procedures applied to macroeconomic predictions remains difficult.

New indicators can inherently come from machine learning models and natural language processing of text-based documents (e.g., annual reports) or network analysis. The latter is of great importance when it comes to transportation. For instance, new indicators can be built based on network analysis in the St-Lawrence Seaway context. Network-based analyses help researchers identify key metrics such as centrality, density, betweenness, etc. Research questions could focus on the networks, the strategic players, major sectors in the SC, transportation modes, etc.

Concerning the interest of complementing more traditional approaches, machine learning techniques may be used to build augmented computational general equilibrium models, where calibrations are not based on static theories but data-based features and updated in real-time.

5.3 | Putting researchers' expectations into perspective with government priorities

In this section, we summarize and classify key facts and opinions that have emerged from our discussions with government experts and CIRANO researchers and the roundtables organized between Transport Canada and CIRANO.

Research interests and observations from the consulted researchers	Needs expressed by researchers with regards to transportation data	Government priorities and observations made by Transport Canada experts
Priority research interests cover the entire "end-to-end SC" and intermodal transportation data interoperability.	Gain access to accurate and updated data on the different production sectors and optimize effective interoperability between transport and trade data.	**Priorities:**
Several data sets held by Transport Canada are difficult to access for specific themes (freight, air passengers); sometimes, it is necessary to go through an internal contact within the department.	Obtain a better overview of transportation networks (land use and networks).	Enhance the current information system and create a single point of access to improve accessibility to data (the present Web site already provides access to approximately 600 databases)

Research interests and observations from the consulted researchers	Needs expressed by researchers with regards to transportation data	Government priorities and observations made by Transport Canada experts
Data collection purposes should be clearly identified (e.g. for regulatory assessment, analysis of the SC or transport infrastructure efficiency, etc.). Likewise, the selection of additional databases from the magnitude of those managed by the different stakeholders is another question to be taken into account.	Researchers know precisely their data needs and have specific contacts at Transport Canada for their works. It would be useful for them to have easy access to a catalogue of data available at Transport Canada. On the departmental side, catalogue management is taken into account in the new IT infrastructure being currently developed. A list is available, but efforts are still needed to improve the classification of datasets.	Improve the visibility of end-to-end SC and strengthen the dialogue among the stakeholders. The project with the Port of Vancouver is well advanced, with data exchanged on several commodities. The SC seems to show greater complexity in central and eastern Canada.
Private transportation companies are reluctant to share their commercial and strategic data. On this aspect, it is critical to define what will be done and who should have access to these data to ensure that these data are interpreted properly. However, the need for data sharing is increasingly acknowledged among stakeholders and governments; sharing will expand progressively soon.	Government priorities and observations made by Transport Canada experts	Acquire additional data to fill the current gaps (marine and trucking), combine trade and economic data, and build additional analytical capacity. Data gaps also appear in interprovincial trade (trucking) due to difficult access to provincial data. Likewise, no information is collected on the last mile.
The lack of interoperability between databases and data formatting problems is a major issue for stakeholders and researchers.		**Considerations on the most appropriate approaches to obtain more data from the private sector in Great Lakes - St. Lawrence Seaway Corridor:
New forms of data analysis (e.g., autonomous data-creating and data-receiving vessels) need also be considered.		Look at whether contracts could be modified on the terms of access and use of such data. Certifications and tax incentives could be other solutions to explore.

Research interests and observations from the consulted researchers	Needs expressed by researchers with regards to transportation data	Government priorities and observations made by Transport Canada experts
Regarding data collection, the researchers would also be interested in knowing the questions and research priorities Transport Canada wish to focus on (competitiveness of SC, efficiency infrastructure).		The visibility program in the Port of Vancouver shows that obtaining data from private stakeholders is possible, whereby data are shared for operational optimization and efficiencies in SC and privacy ensured. However, the model used in Vancouver could face challenges if transposed to the Great Lakes - St. Lawrence Seaway Trade Corridor, where SC and the transport ecosystem are more complex than for a gateway and where urban challenges are also more present. The priorities between the public sector and private companies, which focus above all on their own activities, are often divergent and difficult to reconcile. Regulations compelling stakeholders to communicate their data to the government have already been considered. But this solution would lead to a one-way sharing, as data could not be re-shared thereafter for privacy reasons. Fostering a closer relationship between researchers and government experts should provide an ongoing opportunity for collaborative projects to meet the critical challenges facing the intermodal transportation system in the Great Lakes - St. Lawrence Seaway Trade Corridor.

6 | A COMPREHENSIVE APPROACH TO RISK MANAGEMENT FOR SUPPLY CHAINS

While section 2.10 provided an overview of major risks and trends at the global and national levels, this section deals more specifically with the following two application areas: (1) risk factors of trade and physical SC in the Great Lakes - St. Lawrence Seaway Trade Corridor, and (2) risk factors for digital platforms and data.

6.1 | Risk factors at the trade and supply chain level

6.1.1 | Disruption risks in the SC

Many risk factors can potentially cause disruptions to network operations in uncertain times, including epidemics/pandemics; shortage of critical raw materials/components; shortage of supplier production capacity; cybersecurity breaches; tariffs and trade wars/uncertainty; natural disasters; logistics and transportation problems; supplier financial instability/insolvency; geopolitical events; regulatory requirements/changes; supplier incidents; adverse weather/climate change. Roy (2015) also identified specific vulnerabilities of Canadian ports to unforeseen circumstances such as strikes and more predictable events such as Canadian winter, which can also affect the capacity of railroad companies.

6.1.2 | Canadian trade dependency on the United States

In a recent paper, Martin and Mayneris (2020) shows that Canadian foreign trade dependence on the United States is higher than statistics usually suggest. They examine by commodity, country of production, exporting country, and mode of transportation and show that the United States is Canada's main supplier and a major logistics hub for Canadian imports from outside of the United States.

They assess that almost 80% of total Canadian imports (by value in 2015) originate in the U.S. in one way or another, with over 20 percentage points of this being tied to the U.S. for logistics aspects, not production. Furthermore, more than 90% of imports of goods produced in Mexico are routed through the United States to Canada. The US also serves as a major hub for Canadian imports from China, Taiwan, and South Korea, the share of Canadian imports for these countries transiting through the US ranging from 50% to 60%. This great exposure to a single trading partner from a logistical perspective would raise concerns about the resilience of the Canadian economy if extreme events (pandemics, natural disasters, unilateral decisions on trade policy, civil unrests…) were to hit the US. The authors recommend diversification of the origin of imported products in sectors such as paper, chemical, rubber, or food industries.

Among their recommendation for the economic recovery of Quebec, and referring to this study, Garon et al. (2020) suggest addressing this issue by developing waterways and relying more on marine transportation to help Canadian trade and logistics routes diversify. From a logistics diversification perspective, the concentration of the population and economic activities along the St. Lawrence River is advantageous for marine transport to avoid the logistic chains that transit through the United States, thus reducing Canada's exposure to risks occurring south of the border. For this strategic objective, constructing the new port terminal in Contrecoeur will play a significant role.

6.1.3 | Transportation of dangerous goods (DG)

Industrial firms' supply and distribution choices and materials storage policies are made within a complex regulatory environment with multiple levels of government and often a large number of stakeholders. In contrast to other companies, those handling and moving hazardous materials (such as gases, chemicals, and hydrocarbons) must factor into their operating and logistics strategies the potential risks of these products for workers, the public, and the environment at every link in their SC. As a result, logistics management and risk management are intertwined for companies handling and moving such materials (N. de Marcellis-Warin, Trépanier, and Peignier 2013).

Several CIRANO researchers have developed broad expertise in the logistics chains of DG in Quebec and Canada. Numerous project reports have been published on this research theme in the last 20 years, covering specific fields such as:

- Analysis of regulations related to the transport and storage of dangerous goods (DG). N. D. Marcellis-Warin, Favre, et al. (2006) provide an overview of the different laws and regulations (on public safety, environment, transportation, and work safety and security) that apply to the storage, handling, and transportation of DG in Quebec and that constrain the logistical choices of companies involved in these activities. The issues identified in this study are classified into four categories: overlapping laws, aspects not regulated by law, harmonization problems, and companies' bypass strategies.
- Economic evaluation of transport costs and specificity of the transport of DG. N. de Marcellis-Warin, Peignier, and Lupan (2007) identify, for France and Canada, the cost factors associated with the transport of goods according to the modes used, how they are evaluated, and DG transport's specificities. The study shows that the cost variations between freight and DG transport are due to several factors: Safety measures related to transportation are more expensive; specificities of equipment for transporting DG make them costlier; carriers must have training specific to DG; corrosion of vehicles and equipment due to the characteristics of DG leads to very high costs; transportation is slower, and accidents often generate high losses. The study of N. de Marcellis-Warin et al. (2009) provides a picture of the industrial sectors that manufacture, use or transport DG in Quebec and highlights the province's specificities in terms of industry types and their importance relative to Canada according to 8 indicators: employment, investment, production, revenues, costs, exports/imports, innovation, and environment. A specific database including all the industry sectors under study (defined as a grouping of NAICS codes) and data for 30 socio-economic indicators over 20 years has been created for this project. In the wake of this study, N. de Marcellis-Warin, Peignier, and Warin (2010) present an econometric analysis using the database previously developed to prioritize industrial sectors in Quebec and summary sheets for specific industrial sectors. These summary sheets provide detailed information on the DG manufactured, used, or transported, allowing for a better understanding of Quebec's industrial base and better government decision-making support.
- Analysis of accident databases on transportation and storage of DG. Due to their nature, the regulation requires that accidents occurring during storage, handling, or transport of DG be reported. These reports provide reliable indicators of the inherent risks of logistics activities related to these materials. Most accidents involve compressed gases, flammable liquids, and corrosive materials, and the majority are caused by human error. However, it should be noted that the cause of accidents specified in the databases is not derived from the results of formal investigations but documented from information available at the time of reporting. Besides, distinguishing human error from other error types (such as unfixed mechanical problems) can be challenging. N. D. Marcellis-Warin, Leroux, et al. (2006) give a portrait of causes and consequences of accidents by analyzing the content of existing databases on incidents

occurring during transport and storage of DG, namely those of the Ministère des Transports du Québec (MTQ), Transport Canada, the Commission des normes, de l'équité, de la santé et de la sécurité du travail (CNESST), and the U.S. Department of Transportation. Parameters studied are accident types, factors causing accidents, and their consequences. Their report's conclusion provides a set of recommendations centered on Transport Canada's DGAIS for better documentation of accidents involving DG.

- Description of DG storage and transport activities. N. de Marcellis-Warin, Peignier, et al. (2008) provide an overview of the logistics operations with DG in Quebec and Canada, with trend analysis and comparison across the different modes of transportation. Their report also highlights the following: (1) The storage and transport activities of DG are governed by numerous regulations and sometimes by a complex classification system for the different materials, (2) storage sites in Canada and Quebec are of different types, between those managed by companies producing or transporting exclusively DG and those serving only for the manufacturing process of end products that are not DG, (3) across Canada, the number of injuries and fatalities in accidents involving DG is relatively low. However, these accidents can have significant financial and environmental consequences, (4) the most transported DG in Canada fall into Class 3 (flammable liquids), Class 2 (gases), and Class 8 (corrosives), followed by Class 4 (volatile solids), and (5) in terms of foreign trade, the United States is Canada's first trading partner, with important cross-border movements existing by road and rail with Ontario and Quebec.

The study conducted by N. de Marcellis-Warin, Leroux, et al. (2008) offers a portrait of the logistics strategies and economic incentives guiding Quebec businesses dealing with DG. It aims to (1) show more clearly the interactions of responsibility and risk transfers among stakeholders (producers, carriers, warehousemen, commission agents, and consumers), and (2) identify factors (working conditions, carrier's accident history, and reputation, etc.) driving company's logistics choices. A survey was administered to firms that produce or store DG, based on a questionnaire of approximately 100 questions divided into nine sections: Company identification; Identification of a site where DG are present; Procurement of DG.; Shipment of DG; DG at the identified fixed site; Costs related to supply and shipment of DG; Subcontractors with DG activities; Risk control; Regulations of DG. Based on 106 respondents, the results show that companies outsource activities related mainly to transportation, and to a lesser extent, the loading and unloading of DG. Some respondents think that they can avoid responsibility in case of an accident by subcontracting certain activities, although the regulations confirm the shipper's liability in certain circumstances. Besides, subcontracted carriers are rarely subject to safety audits and do not have long-term contracts, increasing the risk for the shipping company.

The questionnaire was then administered to carriers of DG in the report realized by N. de Marcellis-Warin et al. (2010) and received 211 responses. The results show that most companies involved in the transportation of hazardous materials have adopted appropriate safety measures and are generally aware of the risks posed by the product being transported. Risk management appears to be more of an issue for smaller companies or those that do little transport of dangerous goods and most often do not have the in-house expertise to manage the risks.

In addition, carriers seem to underestimate the risk associated with the different phases of transportation: nearly 80% of carriers consider that the riskiest phase is transportation, whereas the statistics on accidents in Canada suggest that there are twice as many accidents during loading and unloading processes. It would be important to make the industry aware of these figures.

- Multimodal transport of DG. N. de Marcellis-Warin, Peignier, and Trépanier (2011) examine transport-related issues of DG in Montreal from a multimodal perspective, basing their approach on the observation that twice more accidents occur during the phases of loading/unloading than during the phase of transport (see above). Two case studies are developed: (1) the polyester chain in Montreal East involving both carriers and industrial sites, and (2) the Port of Montreal, representing an intermodal platform between the land and maritime modes of transportation.
- Issues specific to multimodal platforms and trans-loading operations of DG in Quebec (focus on hydrocarbons)

CIRANO realized two comprehensive research projects as part of Quebec's strategic environmental assessments for the hydrocarbon industry in the province and Anticosti.

1. A review of existing knowledge related to the land transportation (road, rail, and pipeline) of hydrocarbons and their exploitation (Trépanier et al. 2015).
2. The issues specific to Quebec's intermodal transportation and hydrocarbon transshipment processes (Peignier, Hoang Bui, and Trépanier 2016). First, a provincial mapping of hydrocarbon loading and unloading activities is drawn up, covering aspects such as the number and locations of the sites where these operations are carried out, the modes of transportations existing on these sites, the types of hydrocarbons involved, and the occurrence and causes of accidents. Then, an analysis is made of the regulatory framework related to the loading and unloading of hydrocarbons in Quebec. A roundtable discussion gathering federal and provincial stakeholders was organized. The following observations result from this analysis:

- Multiple requirements from different departments to address the same issue are detrimental to effective regulatory compliance.
- Some regulatory gaps need to be filled: crude oil tanks and pipelines, transfer of petroleum products from one tanker to another, accident reporting threshold.
- There is an important need to review the training requirements for operators and drivers involved in oil loading and unloading operations and for emergency services to ensure a sufficient level of safety.
- Accident databases do not allow for effective feedback in Quebec or comparison with other jurisdictions. Data are not sufficiently updated, and difficulties appear when matching databases due to different data entry fields.

Scientific risk assessment is a necessary tool for implementing risk management policies. Still, the context and circumstances of the specific situation should also be considered to achieve collective objectives in a rational and value-maximizing manner (N. de Marcellis-Warin, Trépanier, and Peignier 2013). In this respect, CIRANO's Barometer on Risk Perception in Quebec, produced through a survey of a representative sample of the Quebec population (approximately 1000 respondents), offers interesting insights: in 2018, 69% of respondents stated that they were opposed or completely opposed to DG transportation in Quebec. Half of the respondents (48%) declared having little or no confidence in their government to manage the transportation of DG (only 10% had complete confidence in their government)[13]. These figures show the critical need to inform the public of the existing mitigation measures.

[13] https://mondo.international/barometre/

6.2 | Risk factors at the digital level

6.2.1 | Cybersecurity

The increased level of online interaction and autonomous operations in global SC make them more vulnerable to cyber-attacks. Many seamless connections between stakeholders characterize SC, and the massive volume of important information exchanged between them provides high exposure to external attacks. Cyberattacks can be inflicted on both hardware and software, wherein malicious malware is integrated.

Many companies outsource their online infrastructure to other organizations to reduce infrastructure costs, create interoperability, strengthen digital security, and mitigate cyber-attacks. Adding third parties creates additional risk if these organizations do not have the correct cybersecurity processes in place. Breaches of security may not result only in critical information being stolen but are also costly for organizations. Wright et al. (2020) cite a survey conducted by market research firm Vanson Bourne, whereby 66% of the 1,300 surveyed IT professionals reported having experienced a software SC attack, and 90% of those surveyed financial costs averaging US$1.1 million.

6.2.2 | Stakeholders' participation in a data platform

No data platform initiative can be successful without an appropriate commitment of the targeted stakeholders. A particular challenge consists of obtaining participation from private entities whose utmost interest is securing ownership and privacy of their data. Thus, creating an open data portal requires thinking about incentives to encourage private companies to share data on the one hand and about a legal framework providing them with guarantees and guidance on the other hand. A data platform can be set up in different ways, relating to the type of access (visible and/or downloadable data), the terms of access, the terms of the licenses associated with the reuse of their data, or the costs of access to the datasets or services developed from these data (Royer et al. 2020).

6.2.3 | Trust of data owners

To take full advantage of the benefits of data sharing, it is essential to instill and maintain trust among SC stakeholders[14]. Sharing must be organized and observe stringent rules, particularly ethics, transparency, and security. Since data can be shared with an infinite number of parties, the intangible nature of this resource raises issues of confidentiality, protection, security of sharing, storage, rights of use, intellectual property, and jurisdiction.

Protecting confidentiality refers to ensuring that data is only accessible to those authorized to access it. For private transportation operators, security issues related to privacy are a priority since they have concerns that others may be using their data and therefore slow down the benefits to SC of the value-added from data sharing.

Data owners must decide what data they want to share for clearly defined purposes of use on the platform. Therefore, the terms of the use consents are critical elements that must be decided upon when setting up a data platform.

[14] https://www.insightsforprofessionals.com/it/storage/data-quality-problems-solutions

6.2.4 | Data quality issues

Data used for analysis must be accurate, complete, available, and updated to achieve the best results in decision-making[15]. A significant volume of information being integrated into analytics models will not compensate for flaws in data and datasets. On the contrary, it may generate broader issues such as making decisions based on skewed results or wasted time and resources. IFP (2018) identified five types of data quality problems:

1. Duplicated data often results from siloed processes and multiple systems recording the same information. Data deduplication tools can help spot and eliminate redundant records through very large data sets.
2. Inconsistent formats, with data covering the same information but stored or inputted in different formats that are not recognized by every system. Examples are dates entered in European (DD/MM/YY) and US format (MM/DD/YY). Inconsistent formats exacerbate duplication issues.
3. Incomplete information, representing a disturbance for big data algorithms.
4. Multiple units and languages (differences in language, script, or units of measurement), creating difficulties as analytics tools do not recognize specific data or know-how to translate them. These issues must be considered, particularly when programming algorithms with international data sets.
5. Inaccurate data, ranging from the incorrect input provided by the source of information to the human error when data are entered manually or into the wrong field. Spotting this kind of data quality issues in the systems can be particularly challenging.

6.2.5 | Data sovereignty

Data sovereignty refers to Canada's right to control access to and disclose its digital information subject only to Canadian laws. Residency refers to the physical location of the data, i.e., where the servers storing it are located. These two terms are not necessarily equivalent (Royer et al. 2020). In general, data stored on servers physically located in Canada are subject to Canadian privacy laws and the laws of the countries they move to when they leave Canada. Data from Canadian companies are therefore not necessarily subject to Canadian regulations. This represents a real issue because Internet access infrastructure means that data may flow across borders.

Many professional services are based outside of Canada, whether cloud computing, data storage, or specialized services for each industry. Furthermore, suppose some cloud providers are partially subject to the laws of another country. In that case, even if the servers that store Canadian data are physically present in the country, Canada's full sovereignty is not exercised. There is a risk of loss of control of the data. Today, knowing exactly where the data is, who owns it, how it will be used, by whom, and what legal and moral authorities guarantee its integrity are questions as crucial as they are unanswered. The issue of data sovereignty is complex and continually evolving with foreign and international laws.

6.2.6 | Technical Skills in cybersecurity and data analytics

Cybercriminals' activities have soared globally, including phishing attempts and attempts to exploit security gaps. Professionals with excellent skills in cybersecurity are highly demanded. In 2019, Gartner already predicted a global shortage of two million cybersecurity professionals for this year, a situation which the current global pandemic has

[15] https://www.insightsforprofessionals.com/it/storage/data-quality-problems-solutions

exacerbated: a 65% increase in demand, driven by big banks, technology giants, and niche info-security companies, has been observed in the US during the first quarter of 2020.

Concerning data analytics, Alicke et al. (2016) identify two significant challenges at the private company's level which restrain the full impact of big data, namely:

1. a lack of capabilities as SC managers - even those with a high degree of technical skill, have little experience with big data analytics and its possibilities,
2. the fact that most companies lack a structured process to explore, evaluate and capture big data opportunities in their SC.

In the field of SC management predictive analytics, Schoenherr and Speier-Pero (2015), who have carried out a large-scale survey with SC professionals, also highlight the lack of scientists with excellent analytical skills as a significant obstacle for realizing its full potential. It appeared from their study that the skills needed most come from the fields of qualitative and quantitative forecasting, optimization, statistics, economics, mathematical modelling, and applied probability.

7 | OVERVIEW OF SOME CASE STUDIES/INITIATIVES IN CANADA AND ABROAD

7.1 | West Coast Supply chain visibility program

The West Coast Supply Chain Visibility Program started in early 2018[16]. Its objective is to create a digital backbone to support enhanced collaboration and optimization of the western Canadian supply chain to develop the Insight-Driven Gateway—enabling a smarter, evidence-based approach to decision making and translating insight into action. The Vancouver Fraser Port Authority, Transport Canada, the Prince Rupert Port Authority, and other Pacific Gateway partners are involved in this program.

It is a multi-phase, multi-year program that will develop and implement a series of operational planning and optimization tools tailored to participating industry members.

These tools will support actions to increase capacity and operating efficiencies across the supply chain. Using business and technology insights, this program will create a comprehensive record system for data related to goods movement and provide insights to unlock the full economic potential of the Pacific Gateway. This work is supported by funding received from Transport Canada through the National Trade Corridors Fund in 2019. By the end of 2022, the program aims to have visibility into the movement of 95% of all cargo through the west coast of Canada.

TABLE 6 The four pillars of the West Coast Supply Chain Visibility Program

Create a digital backbone for SC Visibility	Enhancing stakeholder collaboration and engagement	Developing a comprehensive data set for the western Canadian supply chain	Building capabilities for evidence-based decision making
Invest in a stable and efficient technology architecture that will work for all participants	Engage necessary stakeholders to develop trust and understanding of the inputs and outputs of the SC model	Create a comprehensive and accurate set of SC data that is well-understood and repeatable	Develop a reporting system of record for Western Canadian SC performance
Ensure a long-term stable funding model for the SC technology	Ensure necessary legal and operating agreements are in place to enable cooperation amongst stakeholders	Create the necessary tools and techniques to consistently and effectively extract and transform the required data sets	Develop optimization tools and techniques for advanced analytics and evidence-based decision making
Develop skill-sets and expertise to manage and deliver on the SC program vision effectively	Create a community of interest to advance techniques and further develop data and analytics within the gateway	Create and implement a process to ensure the availability and usefulness of the data sets gathered	Develop forecasting methods and tools to enable future projections of key SC events

[16] https://www.portvancouver.com/wp-content/uploads/2020/12.2020-12-18-Overview-West-Coast-Supply-Chain-Visibility-Program-Overview-Winter-2020-2021.pdf

Create a digital backbone for SC Visibility	Enhancing stakeholder collaboration and engagement	Developing a comprehensive data set for the western Canadian supply chain	Building capabilities for evidence-based decision making
Design and build an effective collaboration model to enable member participation			

The program would provide the following analytics and forecasting capabilities, among others:

- Monitor SC performance across all commodities through a near-real-time digital dashboard available to industry stakeholders
- Predict terminal-specific arrival of railcars, linking cargo loading at origin to loading date at the terminal
- Identify operational constraints and capacity bottlenecks based on live system data and simulations
- Improve import and export cargo forecasting to estimate volumes, identify possible capacity issues, and support long-term operational planning.

There is a complex and large group of stakeholders who all have a role in moving goods through the supply chain in Western Canada. Each of these groups will benefit from the "West Coast Supply Chain Visibility Program" by gaining access to (1) a single and comprehensive system of record for the western Canadian supply chain activity, (2) consolidated end-to-end view of goods movement across the supply chain, where many industry members previously only had data for their portion of the supply chain, and (3) a series of tools that support actions to increase capacity and operating efficiencies across the supply chain.

Data is the foundation of the platform, the metrics, and the analytics, and we understand the importance of data security and data access to all gateway members. The dashboard is being designed to ensure that the data provided by each organization is secured.

Access will be managed so that the competitiveness within the gateway is not impacted:

- All participants will have their unique access to a near-real-time dashboard that will provide reports on key metrics around cycle time, throughput, and efficiency
- Each organization will have a different view of the data, with detailed access to its specific performance data, as well as aggregated views of the collective datasets
- Data agreements are being developed with each participant to ensure that the details around data access and data security are clear and agreed upon
- The program will continue collaborating with participants by developing these agreements to ensure all parties are comfortable with the terms around data access, data use, and data security.

7.2 | National Transportation Research Board

The American Transportation Research Board (TRB)[17] is part of the National Academies of Sciences, Engineering, and Medicine. It provides leadership in transportation improvements and innovation through trusted, timely, impartial, and evidence-based information exchange, research, and advice regarding all modes of transportation. For example, committees, researchers, and staff are currently focused on advancing resilient infrastructure, exploring transformational technology, and caring for the public's health and safety. TRB's mission is divided into three primary roles:

TABLE 7 TRB's primary roles

RESEARCH	CONVENE	ADVISE
200+ publications annually	200+ standing committees	100+ national consensus studies conducted
300+ research projects currently managed	8,000+ active committee and panel members	12+ active consensus study committees
$53 million invested annually in the Cooperative Research Programs	13,000+ attendees at the TRB Annual Meeting	40+ consensus studies that have contributed to changes in legislation
One million+ transportation research records in the online database, TRID	800+ sessions and workshops at the TRB Annual Meeting	
227,000+ links to full-text documents on TRID	100+ webinars annually	
900+ peer-reviewed papers published in the Transportation Research Record: Journal of the Transportation Research Board (TRR) annually	50+ TRB meetings and conferences annually	

Vision

"TRB is where the nation's leaders and the global transportation community turn for information exchange, research, innovations, and advice on current, emerging, and critical transportation issues to foster a high-performing multimodal transportation system that enhances society."

Mission

"Provide leadership in transportation improvements and innovation through trusted, timely, impartial, and evidence-based information exchange, research, and advice regarding all modes of transportation."

Goals

"1. Information Exchange. Provide an impartial forum for sharing information across all disciplines and modes on current and emerging transportation issues and related research and innovation, including transportation's relationship with social, economic, environmental, and other issues critical to society.

[17] https://www.nationalacademies.org/trb/transportation-research-board

2. Research. Create and expand access to knowledge by conducting, sharing, and promoting research on current and future issues in transportation, mainly focused on innovative, implementable practices and technologies.
3. Advice. Provide timely and trusted advice to inform the choices facing decision-makers across all modes of transportation.
4. Collaboration. Promote collaboration on transportation research, education, and technology transfer at international, national, regional, State, and local levels; across public and private sectors; and among transportation providers, users, and other stakeholders.
5. Workforce Development. Develop transportation professionals by providing lifelong learning opportunities and fostering and promoting an environment that continually enhances the transportation professional community's diversity, inclusivity, skills, and capacity.
6. Communications. Enhance the transportation community's knowledge of TRB activities and their impacts, the nation's leaders and public's awareness of the contributions of research to transportation's value, and their understanding of the importance of transportation to society."

7.3 | The CASD data platform in France (IDAN network)

CASD[18] is a public interest group bringing together the state represented by INSEE, GENES, CNRS, École Polytechnique, and HEC Paris created by interministerial decree of 29 December 2018. The Public Interest Grouping (GIP) allows public and private partners to pool resources to implement general interest missions.

The primary purpose of the GIP (a not-for-profit organization) is to organize and implement secure access services for confidential data for non-profit research, study, evaluation, or innovation, activities described as mainly public "research services."

CASD is part of the International Data Access Network (IDAN), which brings together six research Data Centres from France, Germany, the Netherlands, and the UK to facilitate research use of controlled access data between these countries[19].

The SD-Box, a secure access computer box, allows remote access to a secure infrastructure where confidential data is sanctuarized. This data storage and processing place is called a "secure bubble." This "Box" is simple to install and replace and is updated remotely. Coupled with the "waterproof" central IT infrastructure, it forms a coherent set of services controlled from start to finish, guaranteeing the very high level of security that CASD must offer to data producers.

A Scientific Council assists the General Assembly and the Director in foresight, innovation, ethics, and scientific strategy.

A Data Producers Committee assists the General Assembly and the Director on data access conditions, documentation, archiving, and disseminating information.

An Information System Security Policy Monitoring Committee assists the General Assembly and the Director in matters of information system security governance (policy, organization, measures, evaluation, audits, continuous improvement).

[18] https://www.casd.eu/
[19] https://idan.network/

The CASD consortium is responsible for:

1. Within the framework of its research service missions:

- implementing secure access services to confidential data;
- participate in data matching, anonymization, and database building
- participate in the documentation and archiving of confidential data;
- participate in the meetings of the Statistical Confidentiality Committee and collaborate with its secretariat
- contribute to the certification of research results based on confidential data;
- participate in the development of access to confidential data at national, European, and international levels and international levels in conjunction with other data provision mechanisms.

2. In the context of its value-adding missions, in particular with the private sector to:

- provide advice and expertise in its areas of competence to the State and other French or foreign entities
- provide security resources or services in its fields of competence.
- provide data access security technology for private interest purposes.

Key figures

- 368 data sources made available in a secure manner (see the complete list of available sources)
- 923 projects managed and hosted since its launch (see a selection of CASD user projects)
- 674 user institutions for 2919 users of secure data since its launch
- More than 400 publications and communications (articles, book chapters, books, theses, reports, conference papers, etc.), referenced and produced by users of the data made available by CASD

The Data

In the public domain, the CASD now makes data from INSEE, the Ministries of Justice, National Education, Agriculture and Food, Economy, and Finance available… For tax data, an implementing decree explicitly specifies that access must be provided through the CASD.

In health, access to data on all public and private hospital stays in France (ATIH PMSI data), and specific health cohorts are possible via CASD.

In the private sector, many companies are already partners of CASD to increase their data security through external access through collaboration with researchers, start-ups, or consultants. These examples align perfectly with the current “open innovation” approach, combining business know-how, research, and innovation capacities of start-ups.

7.4 | Digital Transport & Logistics Forum (DTLF)

This significant initiative of the EU commission is a group of experts that brings together stakeholders from different transport and logistics communities, private and public. Its objective is to build a shared vision and road map for digital transport and logistics. The DTLF[20] also contributes to identifying needs for EU-level measures and supporting their development and implementation where relevant.

The overarching objective of DTLF is to improve digital interoperability in logistics and freight transport across Europe. It aims to give a coherent strategy to remove technical, operational, and administrative barriers between and within transport modes by utilizing a more efficient electronic exchange of information. This expert group completed its first mandate in June 2018 with a significant report and initiative. It targets full-scale digital interoperability and data exchange in a shared, secured, and trusted transport and logistics dataspace.

The EU DTLF report that "enabling organizations to reap the benefits of data sharing in logistics and supply chain" offers essential and practical solutions to inform our proposed collaboration and data-sharing platform.

It proposes a "federation of platforms" for decentralized information exchange and peer-to-peer solutions, where organizations and authorities implement the functionality of their systems themselves.

As the logistics sector comprises many SMEs and a significant number of prominent companies operating on a global scale, it is unlikely that any one of these companies will be able to act as a dominant player. Accordingly, DTLF suggests that the public sector (in our case Transport Canada and CIRANO) take the lead in developing federated platforms.

- The concept is essentially to interconnect the platforms and harmonize their services, not develop a new centralized solution with its specific functionality. Specifically, the platform backbone ("federative platform") provides interoperability between different platforms created through common protocols to support data sharing services[21].
- This should allow all stakeholders to use the platform of their choice and share data electronically. Individual stakeholders will have a single registration and a single point of connection to their chosen platform, which will apply a logic similar to that currently used to access the Internet.
- If all these stakeholders interconnect within one common data-sharing environment to effectively exchange the required information, they can improve their performance and optimize operational processes.
- This approach's key concepts are total inclusiveness of all logistics stakeholders and public administrations, legal compliance, safety, security, and sustainable logistics operations.
- DTLF analyses show that data sharing will enhance supply chain visibility and bundling capabilities and enable synchronized operation planning for a responsive, resilient, and multimodal transport ecosystem.
- Simultaneously, the administrative burden will be reduced, and authorities will improve their risk assessment capability regarding dangerous and illegal transports. Furthermore, it will enhance all modalities' traffic flows, thus contributing to the sustainability goals and a safer and more secure society.

[20] https://www.dtlf.eu/

[21] (http://www.federatedplatforms.eu/index.php)

8 | SYNTHESIS

8.1 | Federal government data initiatives and CCTD

Data must be considered "as a strategic asset for policymaking, program design or service delivery, or to create value for the public, private, not-for-profit, and research sectors" (Government of Canada 2018a). To this end, a solution must address the current fragmentation regarding the data treatment processes within the transportation sector.

The government of Canada has been investing $2.3 billion in the National Trade Corridors Fund over 11 years to strengthen Canada's trade infrastructure (ports, waterways, airports, bridges, border crossings, rail networks). Transport Canada has put in place its data strategy, and the Government of Canada announced an investment of $50 million over 11 years to build the CCTD. Transport Canada and Statistics Canada collect and share new data, performance indicators, analysis, and transportation research in Canada for enhanced decision-making as part of this initiative. This ambitious project is intended to resolve key challenges identified in "Transportation 2030: A Strategic Plan for the Future of Transportation in Canada."

The CCTD is designed as a single location for authoritative, timely, and accessible transportation data. The Centre links to international and national transportation data, information on how the transportation system performs, and a map of Canada's larger land border crossings, airports, and ports. The Centre supports evidence-based decision-making by addressing transportation data gaps, strengthening partnerships among industry stakeholders, and making strategic transportation information more transparent.

The Transportation Data and Information Hub (TDIH) is being developed as part of the CCTD to make data and information more accessible as well as increasing understanding of the transportation sector and its role in Canada's economy and society. It provides public access to over 600 data sets, national traffic and performance indicators, interactive maps, and analytical reports and tools.

Transport Canada 2021-2022 Departmental Plan establishes one of its priorities to transform the design and delivery of programs and services to Canadians to adapt to a changing world. It includes:

- The use of innovative, user-centric approaches to modernize program delivery by implementing a digital-first service strategy using data analytics and emerging technologies like robotics, artificial intelligence (AI), and virtual reality will transition to a more digital government while balancing ethical and privacy considerations.
- Modernize how Transport Canada oversees and delivers regulations by developing common, data-driven, risk-informed digital inspection processes and providing inspectors with even better data and tools.
- Create a data strategy that supports:
  - transparency and the public's trust in Transport Canada's work
  - open and accessible transportation data
  - better quality data analytics and evidence-based decision making
  - service delivery and reporting on results
- Improve the department's data maturity by working on descriptive statistics, more robust data analytics, and database management as a way of integrating diverse sources of intelligence.

8.2 | Main findings

Our consultations and analysis of government documents revealed a diminishing availability of Canadian transport data for stakeholders and inefficiencies created by (1) information asymmetry between users and carriers, (2) a lack of access to information on supply chains, modes, and overall performance, and (3) to confidential operational and strategic carrier data.

Transport Canada has data available on the air and rail sectors (federally regulated modes of transport and voluntary transmission from industry players) but less for the marine and road sectors. Traceability for numerous goods and commodities is insufficient. The department still needs to enhance its data infrastructure capacities, develop predictive analytics tools, and improve dashboards on the transportation system's performance. Additionally, interactions need to be reinforced with other Government Departments, other jurisdictions to optimize data collection.

Despite its vision and ambitious goals for optimizing data collection and information dissemination in the transportation field, CCTD still has very low visibility among the research community. There is room for improvement in this regard.

Data projects applied to the Great Lakes - St. Lawrence Corridor should be coordinated with the other initiatives underway in the Federal government. For instance, the "Visibility Projects" (e.g., West Coast Supply Chain Visibility Program) in Transport Canada could also provide valuable insights. The consulted researchers identified data access optimization, datasets availability (they must resort to estimates to fill gaps in data), and intermodal data interoperability, standardization (data formatting), and updates as the issues to address in priority. However, the purposes of the data collection and conditions for data access should be specified.

The Great Lakes - St. Lawrence region is North America's most vital transportation and trade corridor due to its critical scale and strategic impact on the foreseeable intensification of continental economic interdependence. The transportation sector in this dense population basin should be a pivotal contributor to net-zero emissions commitments by 2050.

The size and scope of the GLSLTC are only matched by the complexity of its multimodal freight transportation systems and growing urbanization on both sides of the Canada-US border. This region spans many geographic areas and jurisdictions, and serves various commodities and chains. The complexity is exacerbated by the lack of data interoperability and effective collaborations between the different stakeholders within the various jurisdictions.. The Transport 2030 strategy of the Government of Canada recognizes that transport data is becoming less available and that Canada needs to make data a priority for a national transportation strategy.

It is challenging to make evidence-based decisions for federal, provincial, and municipal governments and the private sector in this context. These inefficiencies hurt Canada's ability to compete within North America and with the rest of the world. At the same time, stakeholders share a common and pressing need to use high-quality, timely, and accessible data and analysis.

Data is an essential resource for economic growth, competitiveness, innovation, job creation, and societal progress in general. Innovation and economic performance increasingly hinge on the quantity and quality of data, transforming Canada's economy and society. Data is now at the center of global trade.

On the methodological front, we are also convinced that AI techniques and Data Science should be leveraged to map in real-time, with granular data and new indicators, the GLSLTC's economy, allowing a risk analysis also in real-time.

The 2018 Report to the Clerk of the Privy Council: A Data Strategy Roadmap for the Federal Public Service underscores key challenges:

"How the Government of Canada collects, manages, and governs data—and how it accesses and shares data with other governments, sectors, and Canadians—must change Individual departments and agencies generate and hold a vast, diverse, and ever-expanding array of data, including program, geo-spatial, administrative, sensor and population data. These data are often collected in ways—based on informal principles and practices—that make it difficult to share with other departments or Canadians. Their use is inconsistent across the government, and their value is sub-optimized in the decision-making process and day-to-day operations."

8.3 | Conclusion

The consensus of the studies and policy papers surveyed for this report confirms that interoperability data sharing will enhance supply chain visibility and building capabilities. Likewise, they will enable synchronized operation planning for a responsive, secure, and multimodal transport ecosystem. New models of public-private data-sharing partnerships are considered essential.

Based upon the main findings developed in this report, we consider it necessary to engage and participate with relevant public and private stakeholders in the realization of a common data space by 2030: a strategic asset of Canada's critical intermodal transportation and supply chain infrastructure in the Great Lakes St. Lawrence Seaway Trade Corridor.

To this end, we propose to launch a CIRANO data science pole about transportation and trade as a collaborative network where stakeholders exchange expertise and collaborate to formulate policy and technical recommendations for public authorities and the private sector regarding data management, interoperability, and accessibility in the intermodal transportation and trade system of the Saint Lawrence Seaway Great Lakes Trade Corridor. This collaborative platform or "Carrefour" will:

- provide a forum for structured dialogue, exchange of expertise, cooperation between public, industry, and research stakeholders.
- foster knowledge exchange, skills development, and student engagement.

Methodologies will be developed to allow the collection of new forms of data (real-time, big data). This proposed applied research pole will also promote optimization tools and platform functionalities concepts to unlock the trade corridor's full economic potential and increase efficiencies across supply chains.

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