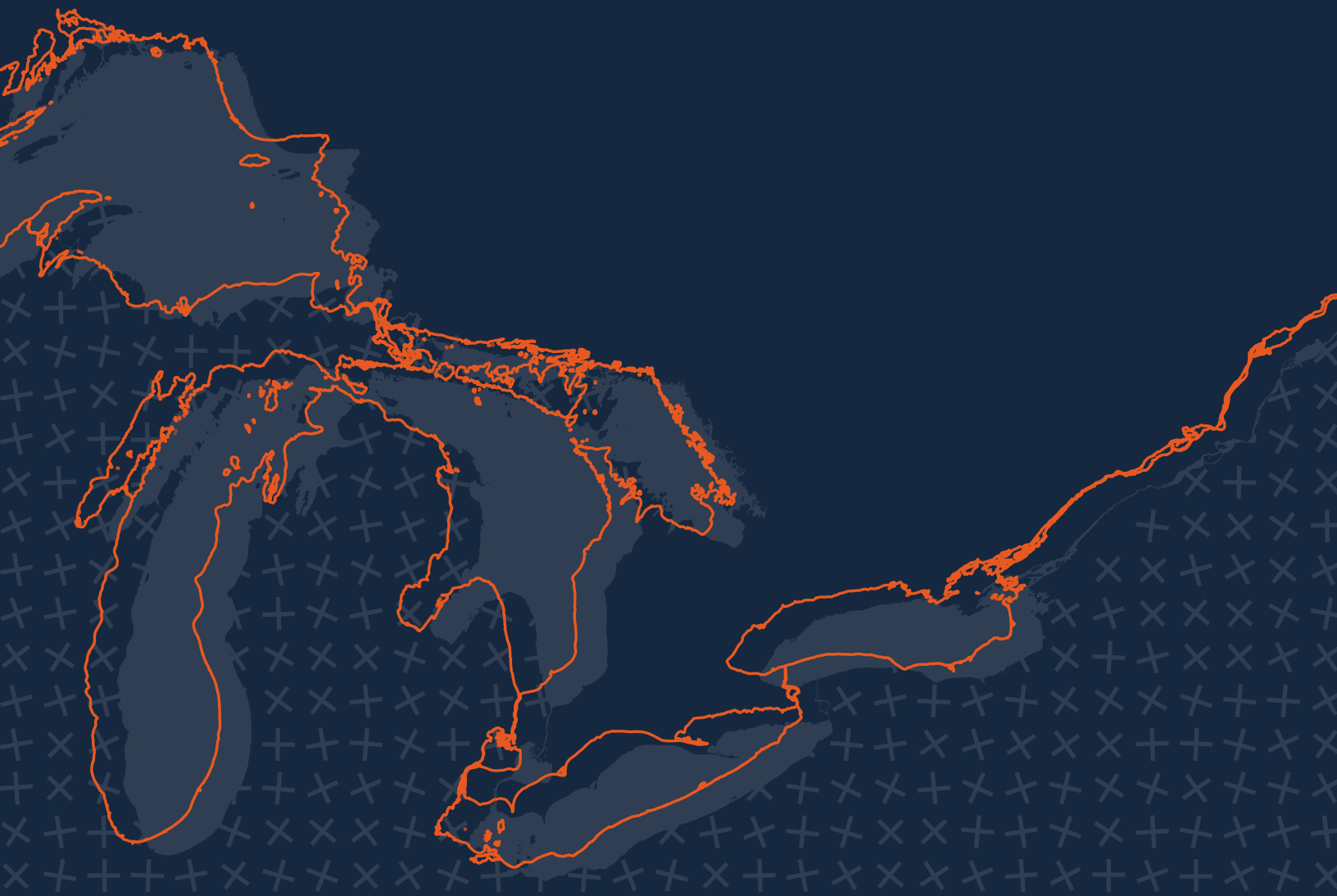

A GVCdtLab REPORT

Improving the Attractiveness and Competitiveness of the St. Lawrence - Great Lakes Corridor

SEPTEMBER 2025



Improving the Attractiveness and Competitiveness of the St. Lawrence – Great Lakes Corridor

September 2025

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Executive Summary

The St. Lawrence–Great Lakes (SLGL) corridor is a strategic economic area with more than 100 million inhabitants and an annual GDP of approximately USD 6.9 trillion. If it were a country, it would rank as the world’s third-largest economy. Historically structured around the St. Lawrence River, the corridor plays a central role in North American trade and transportation. Yet its potential remains underutilized, and it faces numerous challenges. In today’s context of economic and geopolitical uncertainty, the region must rethink its competitiveness and attractiveness. Despite significant recent investments in both the United States and Canada, the SLGL corridor continues to suffer from institutional fragmentation that undermines logistical fluidity and innovation—unlike major European port hubs such as Rotterdam.

This analysis draws on a review of academic and institutional literature, data from the GVCdtLab digital twin project on SLGL trade and transportation networks, and a series of interviews with key logistics stakeholders and public decision-makers. It identifies the region’s opportunities and challenges, highlighting the need for stronger multimodal integration, greater investment in innovation, and deeper collaboration among stakeholders. The study is structured around three pillars: productivity, driven by the optimization of logistics

operations; modernization of physical and digital infrastructure, essential to facilitating trade flows; and resilience and environmental sustainability, supported by workforce training, data sharing, and the inclusion of local and Indigenous communities.

The report recommends that the SLGL region adopt a multimodal platform vision to transform the corridor into an integrated, competitive, and sustainable ecosystem, drawing inspiration from practices observed in leading European logistics corridors and hubs.

Introduction

The St. Lawrence and Great Lakes region (SLGL) is a true economic powerhouse straddling the United States and Canada, structured around the St. Lawrence River, a vital transport artery. Home to more than 111 million inhabitants and generating approximately USD 6.9 trillion in annual GDP, this binational region would rank as the world's third largest economy if it were a country (Council of the Great Lakes Region, 2025). Historically, the SLGL river system has supported regional development by providing bulk transport and connecting industrial hubs. Today, it remains a strategic asset for trade and transport, with untapped potential to enhance multimodal freight efficiency and stimulate sustainable growth.

In the current uncertain economic and geopolitical context, this major economic entity must rethink how to enhance its attractiveness and competitiveness, two concepts that can be defined as follows:

- **Attractiveness** is the corridor's ability to attract resources by offering favourable conditions in terms of economic opportunities, institutions and infrastructure.
- **Competitiveness** refers to the corridor's ability to maintain or improve its global economic position in the face of competition, while ensuring sustainable growth in productivity and living standards.

Canada and the United States recognise the importance of modernising transport infrastructure in this corridor. In recent years, significant investments have been made to upgrade multimodal infrastructure. For example, the bipartisan infrastructure bill passed by the Biden administration in 2021 allocated a historic \$17 billion to U.S. ports and waterways (U.S. Department of Transportation - Maritime Administration, 2025); and, in 2024, nearly \$580 million had been spent on port improvement projects in dozens of states, including the Great Lakes ports (U.S. Department of Transportation - Maritime Administration, 2024). These

investments aim to increase capacity, improve intermodal connections and reduce bottlenecks – reflecting a shift in public policy towards integrated transport solutions. On the Canadian side, initiatives such as Quebec's Maritime Strategy and various federal infrastructure programmes are also directing funding towards ports, trade corridors and digital modernisation. These efforts reflect a shared understanding that strengthening port and river infrastructure is essential to a resilient multimodal freight network, generating benefits for road, rail and maritime modes.

Despite these advances, challenges remain. Compared to multimodal hubs such as Rotterdam, the SLGL corridor suffers from fragmented governance and limited coordination, hindering planning and innovation. While Europe's largest ports operate as integrated platforms under unified strategies, the SLGL remains managed by a multitude of public and private actors often operating in silos. This fragmentation has led to missed opportunities to develop seamless multimodal transport, particularly the sub-optimal use of maritime transport for containers and high value-added freight. By 2026–2035, the region has the opportunity to address these shortcomings through a multimodal SLGL platform equipped with modern infrastructure, digital integration, skilled human resources and an inclusive governance model, paving the way for more efficient and sustainable freight transport.

This report analyses the current state of economic potential and transport networks within this large region, the benefits of enhanced maritime capacity, lessons learned from international best practices, and the roadmap for building a multimodal platform capable of transforming the St. Lawrence ports into catalysts for regional prosperity.

The structure is organised as follows:

- Based on a review of the literature and recent regional data, the first part of the

study presents a detailed portrait of the SLGL region's trade and transport corridor, which is characterised by strong cross-border integration but faces geopolitical tensions, slowing productivity gains and the imperative of decarbonisation.

- The second part provides a review of the theoretical foundations of productivity and a hierarchy of levers for action, placing physical and digital infrastructure as foundations, human capital and innovation as drivers, and AI and data science as optimisation factors.
- The third part focuses on three interdependent strategic pillars identified as levers for increasing competitiveness: 1/ Productivity and logistics efficiency, 2/ Physical and digital infrastructure, 3/ Resilience and sustainability.
- The fourth part presents examples of integrated multimodal ecosystems from which the SLGL corridor could draw inspiration, notably the European Union's European transport corridors policy as an institutional illustration, and the application of the concept of synchromodality at the Port of Rotterdam as a model of integrated coordination at the local level.
- The conclusion proposes a vision for the coming years, accompanied by a series of strategic priorities to make the region a smart and sustainable integrated multimodal ecosystem, similar to other major global hubs.

In terms of methodology,

- Each section includes a literature review to establish the conceptual and theoretical framework for each of the issues addressed, based on about 100 references including academic articles, as well as government and industry reports, publications and statistical tables produced by the transport industry. Where relevant, several examples of international experiences are cited for illustration purposes.
- Our analysis is then applied concretely

to the case of the SLGL region, through the integration of visuals and data tables produced as part of CIRANO's GVCdtLab project, generated in particular in the digital twin of the SLGL region based on more than twenty databases, in order to identify current challenges within the corridor and potential solutions.

- The structure of the report has also been enriched by the lessons we have learned from more than 15 interviews conducted with strategic decision-makers representing various stakeholders in the maritime logistics ecosystem of Quebec and Ontario, including: carriers, importers/exporters, logistics intermediaries, ministries and public organisations, academia and the scientific community. The purpose of these interviews was to gather the perspectives of these various stakeholders in order to highlight the main issues, levers and opportunities and determine priorities for action. They should also help identify data to be explored.

I. A trade and transport corridor

The binational St. Lawrence-Great Lakes corridor: A major economic power

A historically integrated basin representing the world's third largest economy

The SLGL region, which includes Quebec, Ontario and eight US states (New York, Pennsylvania, Ohio, Michigan, Indiana, Illinois, Wisconsin and Minnesota), is one of the most important integrated economic hubs on the planet. If this vast cross-border basin were a country, its gross domestic product would be USD 6.9 trillion in 2024, making it the world's

third largest economy behind the United States and China. With more than 51 million jobs, the region generates nearly one-third of the combined production, employment and exports of Canada and the United States. In 2022, maritime freight and shipping in this network generated a total of CAD 46.8 billion in economic activity in the United States and Canada (Martin Associates, 2023a). It is therefore a vital driver of the North American economy and a highly integrated area in terms of trade and industry (De Marcellis-Warin et al., 2024).

On the Canadian side alone, there are nearly 800,000 businesses active in various industrial sectors, benefiting from direct access to a regional market of 111 million consumers. This area is distinguished by the St. Lawrence Seaway, which offers unique access to intermodal inland ports, efficiently connected by road, rail and pipeline networks. This strategic corridor plays an essential role in the transport of bulk commodities such as minerals, grain and crude oil, as well as containerised freight.

Figure 1 Overview of the SLGL region in a context of global uncertainty

\$6.9T

GDP in 2024
(in USD)

357k

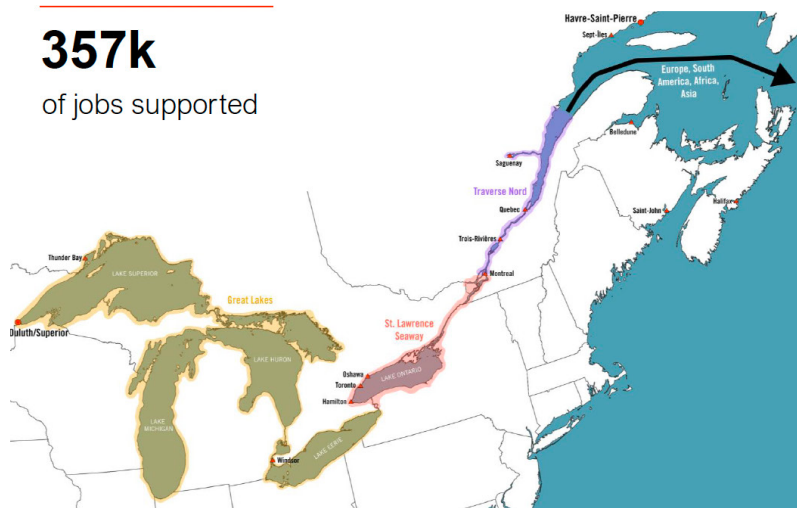
of jobs supported

798k

firms in Quebec
& Ontario

111M

population in
2024



252.1M

metric tonnes of
cargo moved

\$157.2B

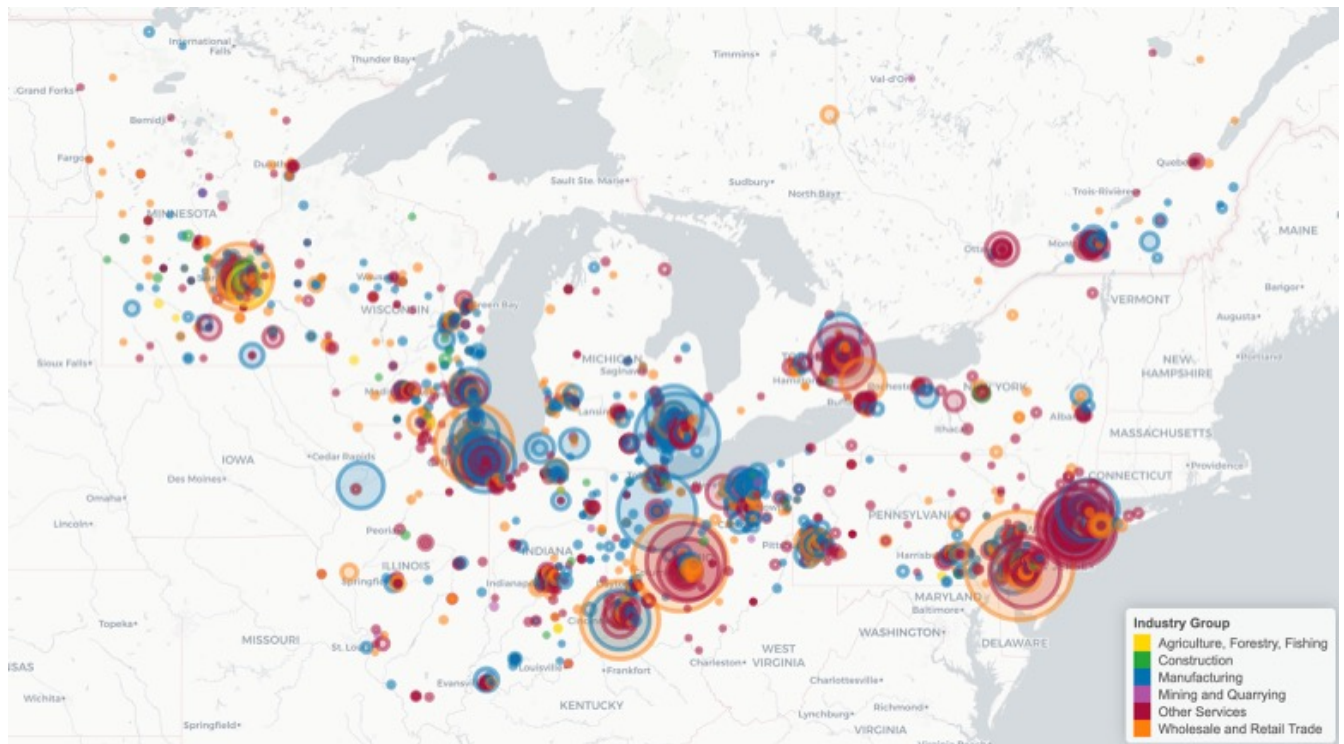
of moved
cargo value

\$66.1B

of economic
activity

Source: GVCdtLab analysis based on data from the U.S. Bureau of Economic Analysis (2025), Statistics Canada (2025e) and Martin Associates (2023a)

Figure 2 Major companies headquartered in the region in 2024



Source: GVCdtLab analysis based on data from the Orbis database (Moody's)

In 2023, approximately 252.1 million tonnes of goods, with an estimated value of \$157.2 billion, were handled in this maritime system (from Duluth/Superior to Havre-Saint-Pierre), generating CAD 66.1 billion in economic benefits in the form of business and transport service revenues, and supporting more than 357,000 direct and indirect jobs in the region (Martin Associates, 2023a).

An important point to remember is that the use of a trade corridor is not directly determined by countries, but rather by the strategic choices of the companies located there, which determine the nature and diversification of their trade. It is exporters and importers who, based on available incentives – such as reduced international trade costs, improved logistical efficiency, or reduced greenhouse gas emissions through innovation, optimisation, and resource sharing – guide their transport decisions. In this sense, transport is not an autonomous driver, but primarily responds to commercial dynamics: it is trade that generates and structures transport demand.

Figure 2 illustrates the distribution of the largest companies established in the SLGL region,

represented by size and sector. Their presence is a significant indicator of the competitiveness and attractiveness of this region, as they act as economic hubs generating jobs, innovation and investment. In addition, these companies take advantage of the corridor's strategic location for their ex-port and import activities, benefiting from direct access to both North American and global markets. They therefore help to consolidate the region's role as an international trade hub, where a multi-modal infrastructure system facilitates the efficient movement of goods.

It is important to note that data on the SLGL corridor is not always directly comparable. Depending on the source, the figures may or may not include domestic traffic, binational or international trade, and sometimes account for tonnage handled differently. These methodological variations explain the discrepancies observed from one report to another and sometimes make it difficult to establish a perfectly consistent picture of the evolution of volumes. Several studies only consider port and maritime flows, which ultimately only reflect the entry and exit points

of the system and do not take into account the logistics, intermodal flows or the real added value of the corridor as a territorialised production chain.

In 2024, the Maritime Chamber of Commerce compiled data on the physical volume of traffic in the SLGL corridor. It estimates that more than 142 million metric tonnes of goods transited through the maritime corridor. 26% of this tonnage (approximately 37 million metric tonnes) transited through the St. Lawrence Seaway, an increase of 12.8% over the previous year (Chamber of Marine Commerce, 2025).

According to the United States Government Accountability Office (2018), annual traffic exceeded 60 million tonnes in the 1980s. It declined in part due to deindustrialisation, increased competition from rail and road, the limited navigation season and vessel size constraints (“Seawaymax”). Several analyses point out that the St. Lawrence Seaway is currently underutilised relative to its design capacity. However, the Seaway remains a strategic link for heavy bulk cargoes such as iron ore, grain and petroleum products.

Historically, this river-maritime route has played a fundamental role in the economic development of the North American continent, facilitating the intensification of trade in goods and raw materials, the gradual integration of markets and the growth of riparian regions (Olson & Suski, 2020). The opening of the St. Lawrence Seaway in 1959, connecting the Great Lakes to the Atlantic Ocean, stimulated the growth of trade in bulk commodities and manufactured goods, gradually integrating the Canadian and American markets around the Great Lakes. Geographical advantages (navigable waterways, rich land) combined with major infrastructure investments led to the emergence of a colossal industrial powerhouse, centred on automotive manufacturing, steel, aerospace and agri-food. Bilateral agreements such as the 1965 Automotive Pact and the 1994 North American Free Trade Agreement (NAFTA) have strengthened the integration of value chains in the region, particularly in the manufacturing sector.

The strategic value of this region lies in particular in its intrinsically multimodal nature, i.e. a system linking maritime, rail and road transport, logistics platforms, industrial zones and a group of local authorities in the most populous and active states and provinces in the East.

Several successes illustrate past cross-border cooperation. Since 1909, the International Joint Commission has applied the general principles of the Boundary Waters Treaty between Canada and the United States to manage cross-border water disputes and issues on a case-by-case basis (International Joint Commission, 2023). Similarly, the joint management of the Great Lakes through the Great Lakes Water Quality Agreement (1972) is a notable example of collaborative action to protect a crucial environmental resource while supporting the regional economy. Furthermore, the Conference of Governors and Premiers of the SLGL Corridor (established in the 1980s) has helped harmonise regional economic policies and plan coordinated infrastructure investments. All of these concerted efforts have helped to make the SLGL basin a relatively homogeneous economic area, with integrated logistics infrastructure (a dense motorway and rail network, interconnected ports, major international bridges) facilitating the smooth transport of goods.

Canadian-American interdependence rooted in the SLGL region

At the national level, Martin & Mayneris (2020) show that Canada’s dependence on the United States is greater than is generally believed. The United States is not only Canada’s main supplier, but also serves as a logistics hub for many goods from other countries: nearly half of imports from non-American suppliers transit through American territory. In total, approximately 80% of Canadian imports are linked to the United States, either because the goods are produced there or because they cross the United States to enter Canada.

Value of trade flows between provinces and states in
Table 1 the SLGL region, 2024

Importer	Exporter	Value (Millions USD)
Illinois	Ontario	10,814
Illinois	Quebec	5,084
Indiana	Ontario	8,309
Indiana	Quebec	3,077
Michigan	Ontario	44,994
Michigan	Quebec	3,117
Minnesota	Ontario	2,228
Minnesota	Quebec	1,073
New York	Ontario	13,226
New York	Quebec	8,529
Ohio	Ontario	11,178
Ohio	Quebec	6,045
Ontario	Illinois	14,025
Ontario	Indiana	14,863
Ontario	Michigan	29,264
Ontario	Minnesota	4,376
Ontario	New York	19,671
Ontario	Ohio	22,757
Ontario	Pennsylvania	10,114
Ontario	Wisconsin	6,954
Pennsylvania	Ontario	8,951
Pennsylvania	Quebec	5,344
Quebec	Illinois	952
Quebec	Indiana	636
Quebec	Michigan	727
Quebec	Minnesota	333
Quebec	New York	2,669
Quebec	Ohio	1,351
Quebec	Pennsylvania	1,508
Quebec	Wisconsin	155
Wisconsin	Ontario	3,030
Wisconsin	Quebec	1,842
Total		267,198

Source: GVCdtLab analysis based on data from Statistics Canada (2025a)

This integration is reflected in intense, two-way trade flows, particularly in the Great Lakes basin. As shown in Table 1, each year, approximately \$267 billion in bilateral trade takes place between Canadian provinces and US states in the SLGL region. This exceeds the total volume of trade that this region conducts with major external partners such as China, Mexico or the European Union. Indeed, Canada is the leading export market for each of the American states in the region, and conversely, the Canadian provinces of the SLGL export heavily to these states. Supply chains are closely intertwined on both sides of the border: for example, it is estimated that 78% of regional imports from the neighbouring country are intermediate inputs (raw materials, components) intended for incorporation into local production. A striking symbol of this interdependence is the Ambassador Bridge (Detroit–Windsor), where nearly 10,000 trucks and the equivalent of US\$500 million in goods pass through daily, representing 25% of bilateral trade between Canada and the United States at a single crossing point (Council of the Great Lakes Region, 2017).

This dependence varies depending on the product and sector. Imports of vehicles, paper and printing products are heavily linked to the United States, while the pharmaceutical and textile sectors are less exposed. Imports from Mexico, China and Korea mainly transit through the United States, highlighting that country's central role as a logistics hub. Analysis of the direct and indirect American content of inputs shows that Canadian manufacturing industries are heavily dependent on the United States, while the service sector remains less vulnerable.

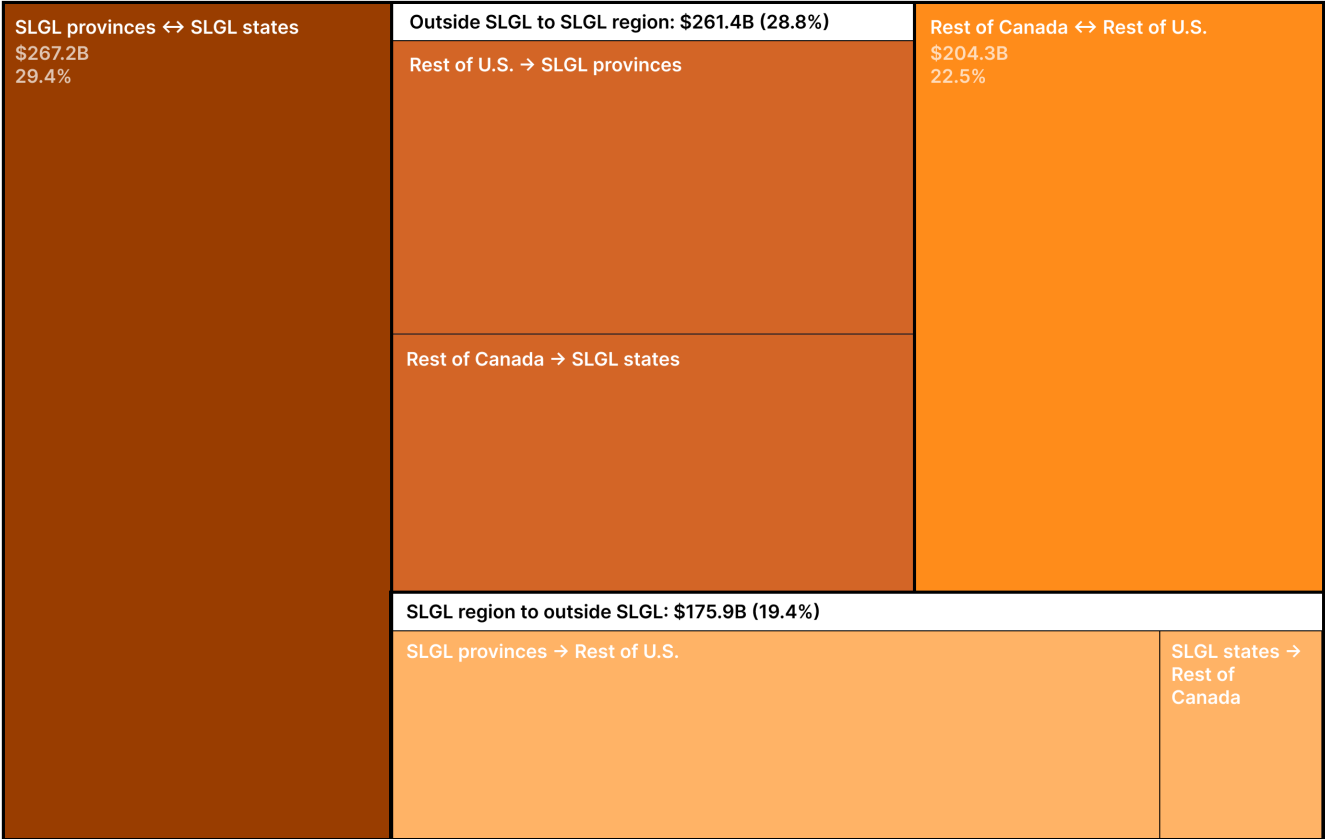
As shown in Figure 3, when we distinguish between Canadian-American trade within and outside the SLGL region, we see that intraregional trade is predominant, representing C\$267.2 billion, or 29.4% of total trade between Canada and the United States.

Figure 4 illustrates these internal flows, whether between provinces or between states. The case of Ontario and Michigan is a good illustration: Michigan imports more from Ontario than any other US state, while Ontario imports more from Michigan than from Quebec. This dynamic reflects strong cross-border integration, supported by common supply chains in several key industrial sectors, notably automotive in Ontario and aerospace in Quebec

In the context of current geopolitical challenges, the dynamics of cross-border trade between businesses are undergoing adjustments. As shown in Figure 5, in relative terms, Quebec businesses export more to other Canadian

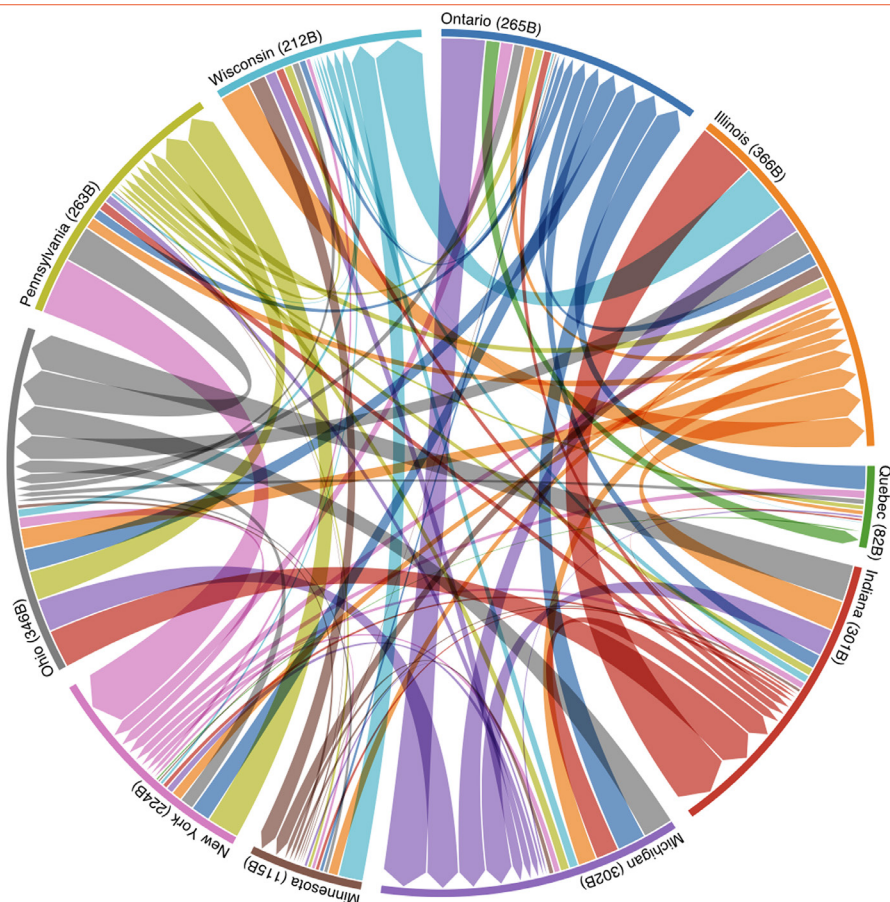
provinces (39%) than their Ontario counterparts (32%). However, in both cases, the share of international trade remains higher than that of interprovincial trade. Thus, 76% of Ontario’s exports are destined for international markets, reflecting a greater dependence on foreign trade than in Quebec, where this proportion is 68%. The visual also highlights differences in the pace of post-COVID recovery between the two provinces, both in terms of exports and imports.

Figure 3 Trade between Canada and the United States by exporting-importing region, 2024



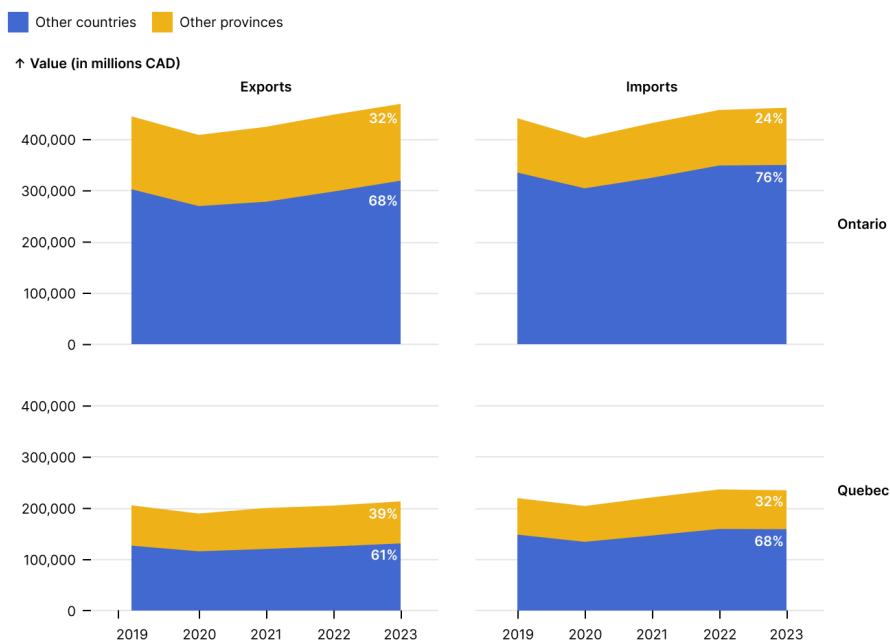
Source: GVCdtLab analysis based on data from Statistics Canada (2025f)

Figure 4 Trade flows within the SLGL region, 2024



Source: GVCdtLab analysis based on data from Statistics Canada (2025f)

Figure 5 Proportion of interprovincial and international trade



Source: GVCdtLab analysis based on data from Statistics Canada (2024b)

Sectoral specialisations and potential for diversification

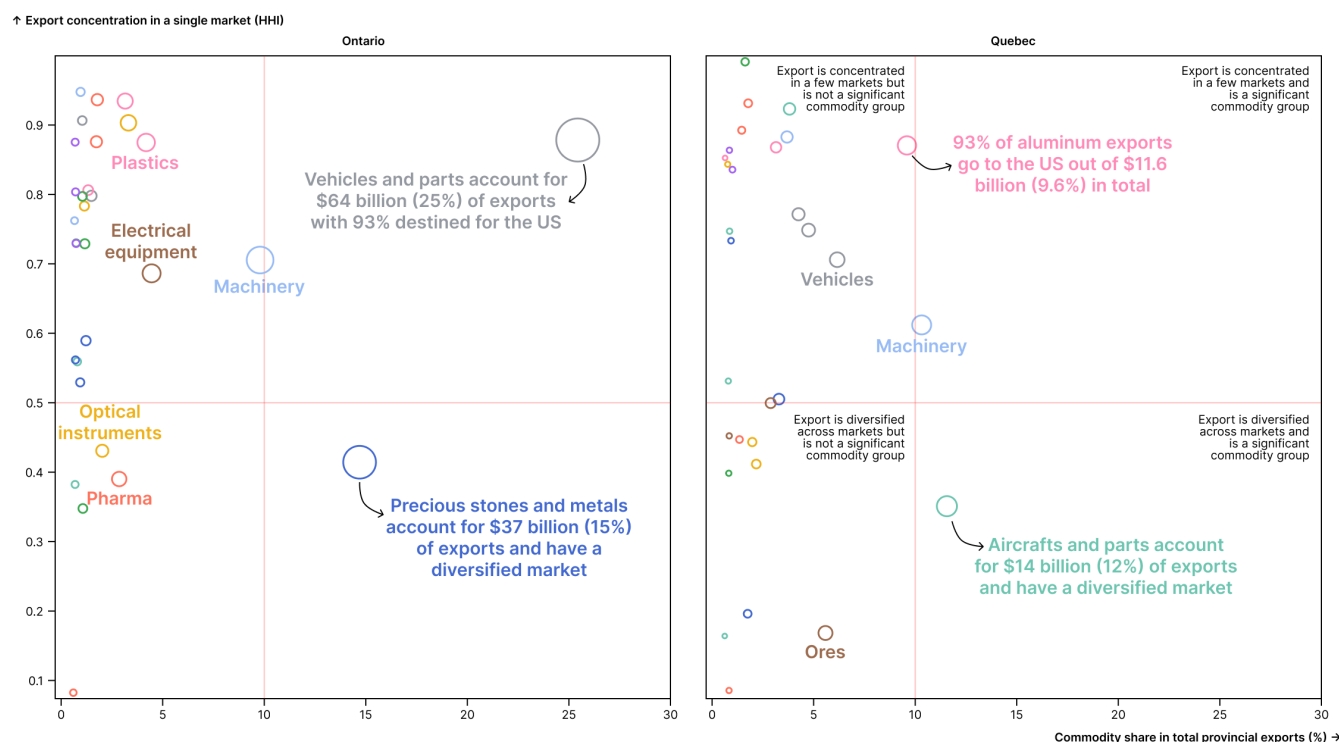
Figure 6 illustrates the extent to which the nature of trade depends on the industrial sectors located both within and outside the region. The data in this visual show that in Ontario, the main industries in terms of value are automotive, precious stones and metals, and machinery, with more than 93% of automotive exports destined for the US market. In Quebec, aluminium, machinery and aeronautics play a central role, with more than 93% of aluminium exports also going to the United States. Beyond these specialisations, however, certain sectors offer significant potential for diversification into new markets outside the United States. This is particularly the case for critical minerals, cereals, crude oil and liquefied natural gas (LNG), where growing demand could lead to rapid export expansion.

Taking the example of Ohio, a US state in the SLGL region, total exports to Ontario and Quebec amounted to USD 18 billion in 2023. The most important export sectors to Canada are mainly automotive parts, industrial machinery

and aerospace parts (Ohio Department of Development, 2023).

At a more local level in the region's municipalities, DiCapua (2025) indicates that several American cities are heavily dependent on Canada in terms of exports; cities in the north of the country generally rank higher due to the existence of interconnected railways, ports and motorways. According to a ranking by the Canadian Chamber of Commerce in 2025 (Tapp, 2025), **10 American cities have a dependence on exports to Canada greater than or equal to 10%**; the most significant being Detroit (39%), Chicago (31%), Columbus (33%) and Cleveland (30%), and Pittsburgh (25%). **On the Canadian side, seven of the ten urban centres most exposed to US tariffs are located in Ontario and Quebec.** Southwestern Ontario (Kitchener–Cambridge–Windsor) ranks third among the most vulnerable regions in the country, followed by Hamilton and the province of Quebec. **In Ontario, the value of exports to the United States accounts for more than 40% of the GDP of the Kitchener–Cambridge–Windsor region, mainly automotive parts,**

Figure 6 Regions have different industries but their export markets are highly concentrated



Source: GVCdtLab analysis based on data from Statistics Canada (2024a)

Case study: Aluminium and the GVCdtLab CCA diversification indicator

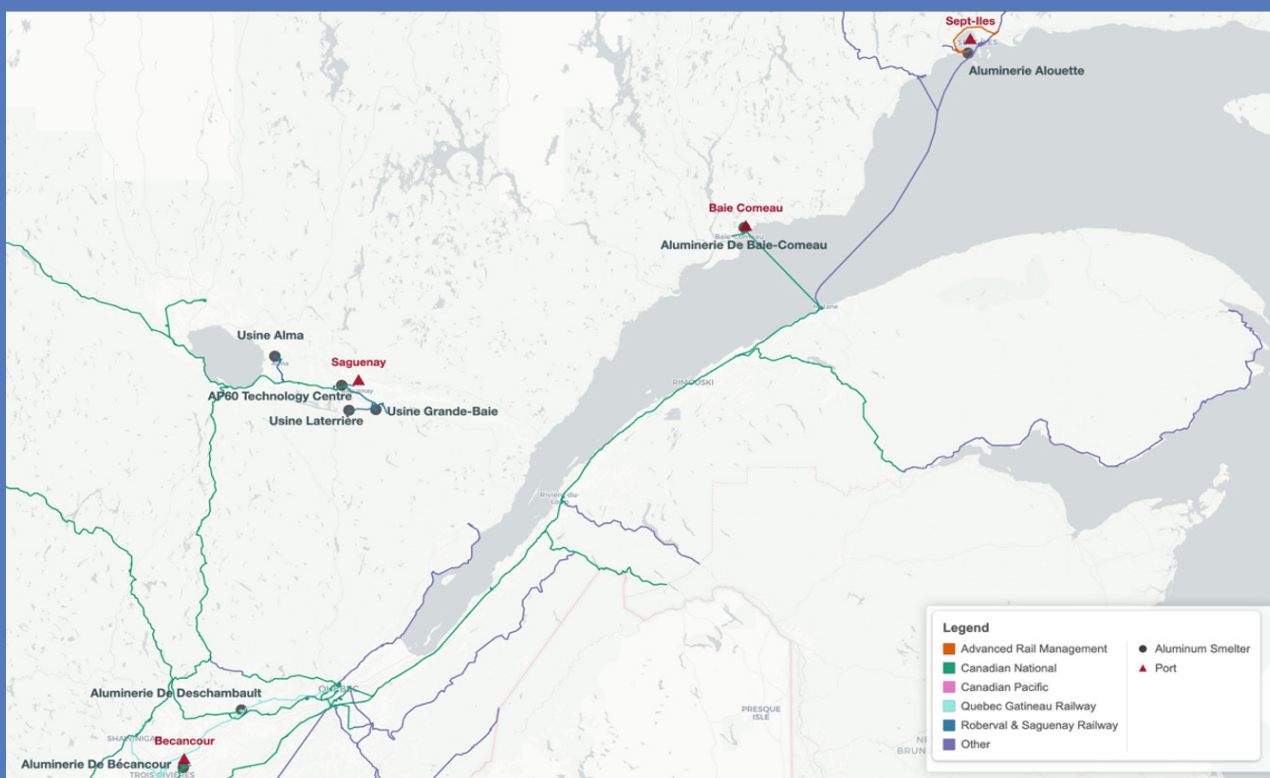
Aluminium is one of the country's most exported products: Canada exports approximately 3.3 million tonnes of aluminium per year, including 2.7 million tonnes to the United States (Natural Resources Canada, 2025), with a total of three companies operating in this sector. However, in order to produce this aluminium, Canadian companies must first import bauxite and alumina. Once imported, these raw materials are then processed in aluminium smelters to produce aluminium. Canada has ten smelters, nine of which are located in Quebec.

It should be noted that, despite the need for Canadian companies to import several inputs, the country remains one of the world's leading exporters of aluminium. This is due to several factors. First, Canadian companies invested early and significantly in aluminium smelters;

the first potline began producing aluminium in 1926 (Aluminium Association of Canada, 2025). Secondly, it is no coincidence that eight of the nine smelters are located in Quebec: aluminium production in this province benefits from relatively low energy costs, thanks to hydroelectricity.

A map of Canada's ten aluminium smelters shows that they are systematically located near waterways, reflecting the sector's dependence on imported inputs (mainly from overseas). The main bauxite-producing countries include Australia, Guinea and China. Overlaying the Quebec rail network also shows that the sites are connected to the rail system. These structural elements shed light on how the supply chain works: Canada imports most of its bauxite and alumina by sea, then exports aluminium—

Figure 7 Map of aluminium smelters and main ports of entry for aluminium inputs



mainly by rail and truck and, to a lesser extent, by sea—to the United States (United Nations, 2025).

In the current geopolitical context, Canadian aluminium companies may need to re-evaluate their destination markets and trade partnerships. Since June 2025, the United States has imposed a 50% tariff on aluminium imports from Canada, an increase of 25 percentage points from the previous rate of 25%. To cope with this increase, Canadian companies will turn to new markets. However, this strategy raises two questions: **(1) Does Quebec have the necessary infrastructure? (2) Which new markets would be interested in the prices offered by Canadian companies?**

As for the first of these questions, it appears that port infrastructure is already sufficiently developed to accommodate an increase in overseas exports. For example, the president of the Port of Bécancour, Donald Olivier, recently indicated that the port is ready if the Bécancour aluminium smelter or other companies in the industrial park decide to develop new markets (ICI.Radio-Canada.ca, 2025).

To answer the second question, Canadian aluminium trade must be attractive in terms of price, both for Canadian companies and for those in the new import market. With this in mind, a new indicator has been developed, namely cost-based comparative advantage (CBCA). CCA measures the maximum margin at which Canadian companies remain competitive with other exporters for a given product.

To see how CCA is calculated, let us consider three existing trade flows:

- one where Canadian companies export to a country they wish to move away from;
- one where an exporting country that Canada could compete with ships the same product to a potential market;
- one where Canadian companies already export the product in question to the potential market (but may have an interest in

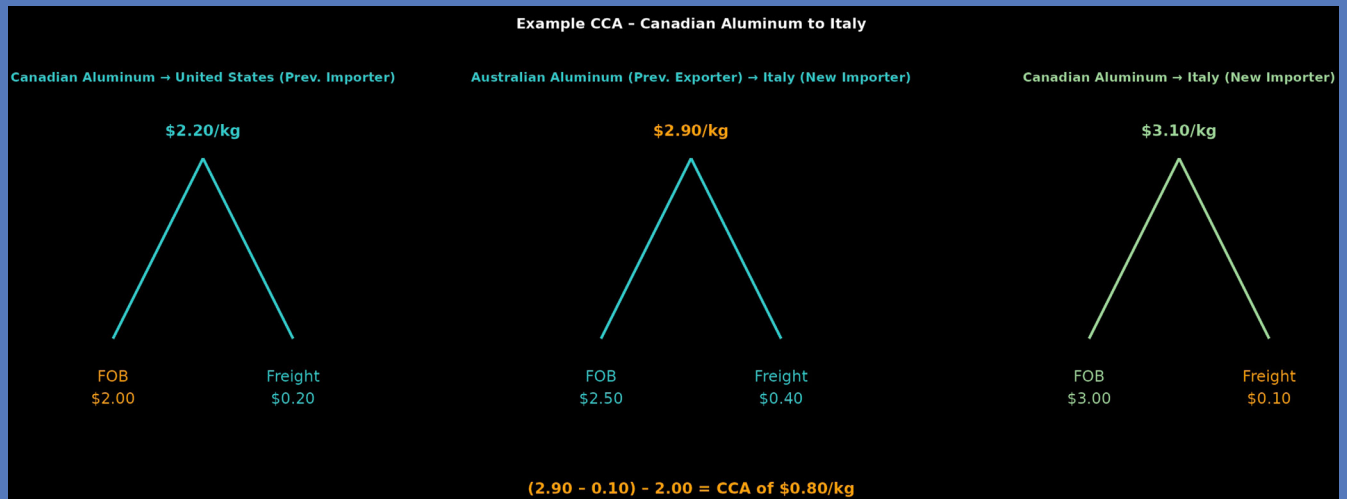
exporting more).

The CCA tells us whether Canadian companies and importing companies in the potential market (i.e., the third flow) would have an interest, in terms of costs, in increasing trade in a product between themselves rather than continuing to trade as much with the partners mentioned in flows 1) and 2). More specifically, let's start with the cost, insurance and freight (CIF) value of a product. This is the sum of two components: a free on board (FOB) value, i.e. the market value, and transport costs. First, we take the average CIF value per kilogram for a given product between the exporter to be competed with and the potential importer. This is the CIF value of flow 2). We then subtract the average transport costs from Canada to that same importer for the same product (i.e., the transport costs for flow 3); the difference is a hypothetical maximum FOB value not to be exceeded. This value is then compared to the average FOB value currently charged by Canada for this product to a reallocation market (from which volumes would be redeployed). The CCA is the difference between these two FOB values: if it is positive, it means that redirecting volumes of the product in question to the new importer will, on average and at current prices, be advantageous for both parties. A numerical example follows to illustrate the calculation. Given the current geopolitical context, we have chosen the United States as the current importer from which Canada is considering turning away; Australia, a major producer and exporter of aluminium, as the reference exporter; and France, a major importer of aluminium, as a potential market to which Canadian companies could increase their shipments. In reality, an CCA calculation can be made for hundreds of thousands of combinations of countries and products; the countries and product selected here are for illustrative purposes only.

Note that three countries (in addition to Canada as the main exporter) are always involved in calculating a CCA:

1. a current importer of Canadian products,

Figure 8 Example of CCA calculation: Canadian aluminium to France



which Canada may consider turning away (in the example above, the United States);

2. a potential new importer likely to replace the current importer (France);
3. a current exporter to this new importer, which Canadian companies could displace with lower prices (Australia).

The objective is to assess whether, at observed prices, it would be advantageous for Canada and for the new importer for Canada to reallocate part of its exports from the current market to this new market. Specifically, instead of Canada

exporting aluminium to the United States while Australia exports to France, we examine whether Canada and France would benefit from increasing flows from Canada to France. In this scenario, if the CCA is positive, replacing two existing trade routes with a single route would be more cost-efficient. In the example above, an CCA of US\$2.50/kg means that Canadian companies could increase the price at which they currently sell aluminium to US companies by US\$2.50/kg, redirect those sales to French companies and remain, on average, price competitive with Australian suppliers.

machinery and agricultural products (Tapp, 2025). **Quebec produces 90% of Canada's aluminium, the vast majority of which (90% of Canadian national production) is exported to the US market.** Several industrial hubs structure this sector, notably the aluminium smelters located in Saguenay, Baie-Comeau and Trois-Rivières (Natural Resources Canada, 2025).

An integrated, region-centred multimodal transport system

Any change in business practices has a direct impact on transport dynamics. As illustrated in Figure 9, 50% of the value of Canadian goods exported to the United States is transported by truck, while rail and maritime transport play a more limited role. In contrast, exports to other countries around the world rely almost exclusively on maritime and air transport. If trade with these markets were to intensify, it would be essential to strengthen rail and road connections to ports in order to support this reorientation of trade flows.

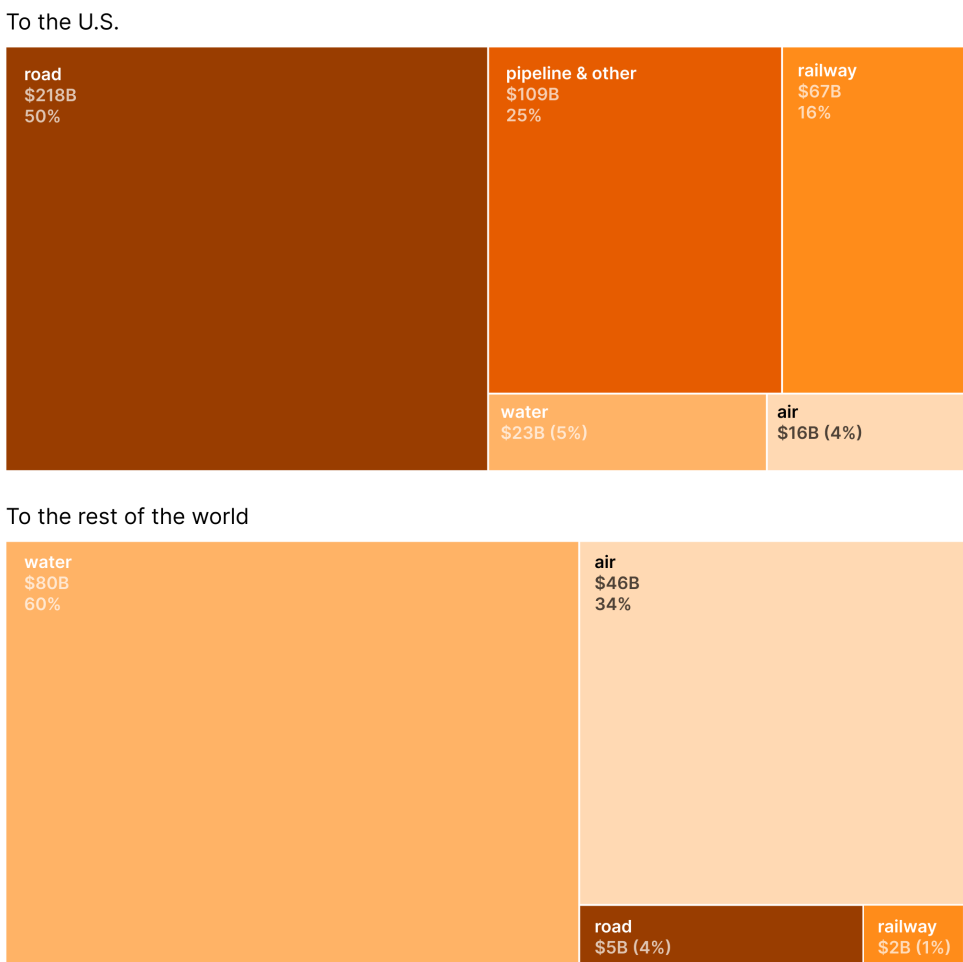
Within the SLGL corridor, most transport flows are heavily oriented towards bulk cargo. While the Port of Montreal is the region’s main container port, other port facilities in Ontario and neighbouring US states handle volumes that are mainly or almost exclusively dedicated to dry bulk (minerals, cereals) and liquid bulk (hydrocarbons and chemicals). This division of roles creates distinct dynamics and challenges: while the Port of Montreal faces issues related to the growth of containerised traffic, urban logistics and intermodal connectivity, bulk ports are more concerned with issues of specialised handling, seasonality of flows and dependence on certain industrial sectors.

In 2023, according to the report by Maritime Innovation (2025), 2,199 ship movements were recorded on the St. Lawrence and Saguenay

rivers, a 2.7% decrease from the peak reached in 2022 (2,260). Between 2019 and 2023, the annual average is around 2,050 movements, with the most sustained trade observed between the ports of Quebec City and Montreal. Just over 24% of these movements took place between Quebec ports, mainly to transport liquid bulk (such as hydrocarbons) and solid bulk (such as minerals). Figure 10 extracted from this report shows the main solid bulk transport links; the associated analysis indicates that the Havre-Saint-Pierre–Sorel route accounts for 74 trips (8.6% of traffic), mainly related to the transport of ore from Rio Tinto to its Sorel plant. Other notable routes involve cement transported from Port-Daniel to Côte-Sainte-Catherine (McInnis cement plant) and iron ore transported from Port-Cartier to Contrecoeur (ArcelorMittal).

“The majority of these transits between ports are short sea shipping (SSS), a key element of Quebec’s transport chain, essential for moving goods over short distances.” (Maritime Innovation, 2025). “Quebec’s ports play a key role in international trade, particularly in trade with Europe and North America, but also nationally in trade with the Great Lakes and the eastern provinces of Canada. Compared to 2010, when more than 117 million tonnes of cargo were handled, there has been significant growth. In 2019, a peak was reached with nearly 157 million tonnes handled, an increase of more than 33% compared to 2010. After a gradual recovery in 2021 and 2022 following the pandemic period, the 2019 peak was matched with nearly

Figure 9 Modal distribution of transport flows in the SLGL region



Source: GVCdtLab analysis based on data from UN Comtrade (2024)

Origine

Origine	Proportion
Baie-Comeau	5.1%
Bécancour	3.2%
Contrecoeur	6.3%
Côte-Sainte-Catherine	2.1%
Forestville	0.8%
Gaspé	0.4%
Grande Entrée	4%
Gros-Cacoma	3.6%
Havre-Saint-Pierre	4.7%
Matane	0.9%
Montréal	5.8%
Pointe-Au-Fic	0.1%
Port-Alfred	8.1%
Port-Carrier	14%
Port-Daniel	1.6%
Québec	12.3%
Rimouski	0.7%
Saguenay	2.8%
Sept-Îles	5.3%
Sorel	8.6%
Trois-Rivières	7.2%
Valleyfield	0.5%
Autres	1.9%

Destination

Destination	Proportion
Baie-Comeau	2.6%
Bécancour	0.8%
Contrecoeur	8.9%
Côte-Sainte-Catherine	2.8%
Forestville	0.8%
Gaspé	0.2%
Grande Entrée	3.7%
Gros-Cacoma	3.6%
Havre-Saint-Pierre	4.6%
Matane	0.9%
Montréal	7.7%
Pointe-Au-Fic	0.1%
Port-Alfred	0.6%
Port-Carrier	20.3%
Port-Daniel	1.4%
Québec	12.4%
Rimouski	0.7%
Saguenay	4.4%
Sept-Îles	3.5%
Sorel	9.7%
Trois-Rivières	6.3%
Valleyfield	2%
Autres	1.9%

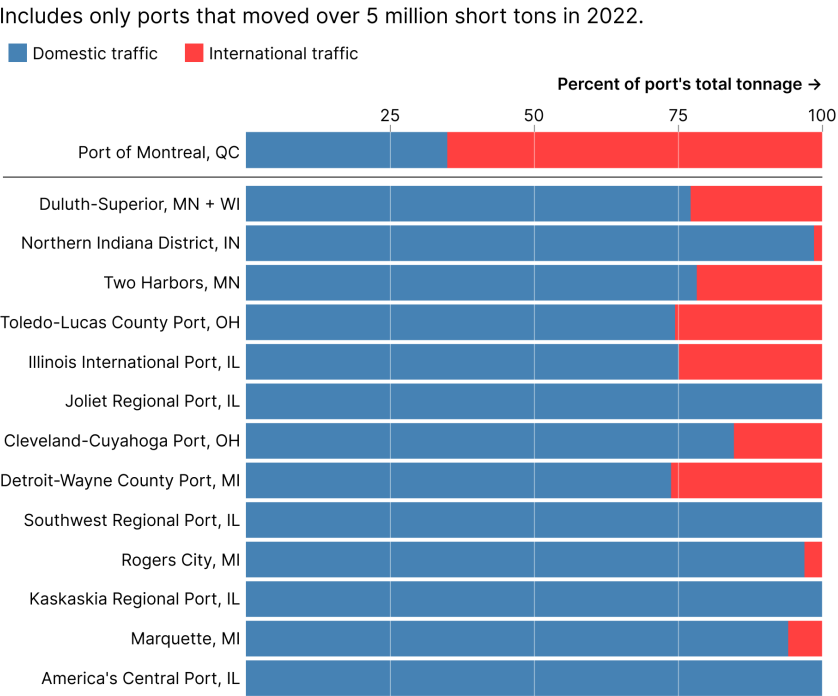
Sources : AIS, SIM, IMAR

Source: Maritime Innovation (2025)

accounts for 70% of volumes handled. **These flows consist mainly of inter-port connections within the Great Lakes network (92%), while intra-port movements (movements between facilities within the same port) and connections with inland waterways remain more marginal.** The international trade share of these ports is mainly concentrated on trade with Canada. Cargoes consist mainly of raw materials such as iron ore, limestone, salt and coal, both for domestic and cross-border. Exports to overseas markets are more diverse, including ore, cereals and coal (GVCdtLab, 2025c). **These two visuals confirm the central role of American ports in the logistics of bulk supply chains for industries in the SLGL region.**

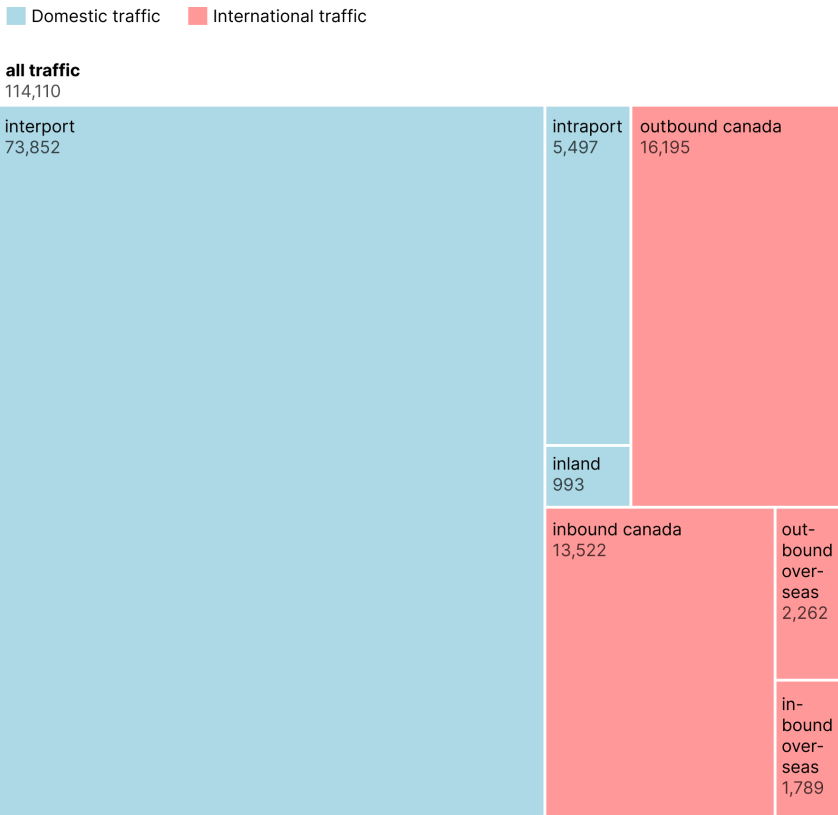
With regard to freight traffic handled by US Great Lakes ports in 2023, Figure 12 also highlights the strong predominance of domestic trade, which

Figure 11 The ports of the Great Lakes on the American side are primarily domestic in nature



Source: GVCdtLab analysis based on data from the Port of Montreal and the U.S. Army Engineer Institute for Water Resources

Figure 12 Goods flows in American ports on the Great Lakes, 2023



Source: GVCdtLab analysis based on data from the U.S. Army Engineer Institute for Water Resources

An integrated area with geopolitical and structural challenges

Geopolitical challenges

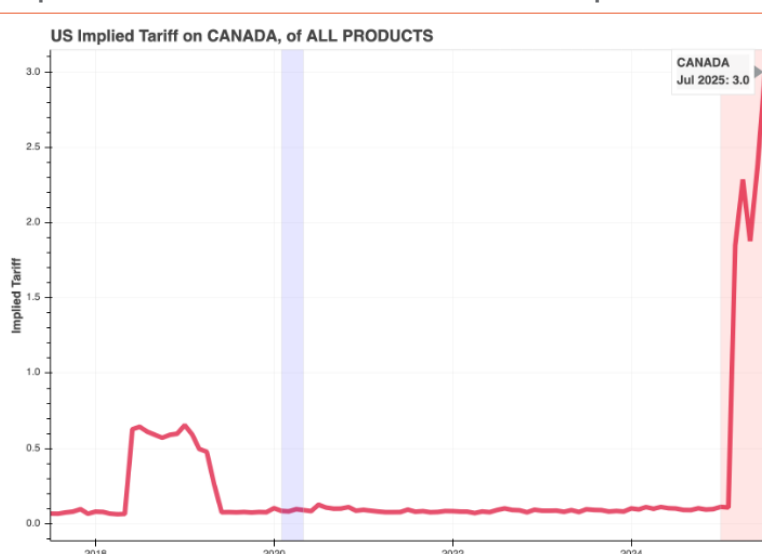
On the geopolitical front, the rise of protectionist trade policies and tensions between major blocs have created fears for this region, which is heavily dependent on foreign trade. The trade war initiated in 2018 by the United States (tariffs on steel and aluminium, threats to the automotive industry) highlighted the vulnerability of the SLGL corridor's manufacturing sector to unilateral decisions on both sides of the border. Although NAFTA was replaced in 2020 by the Canada–United States–Mexico Agreement (CUSMA), ensuring the continuity of North American integration, the climate of uncertainty has slowed some investments. In addition, enhanced border security measures since 11 September 2001 have made border crossing procedures more cumbersome, requiring technological solutions (trusted traveller programmes such as NEXUS, pre-clearance systems) to reconcile security and trade flow.

Since the start of the tariff war initiated by the US administration in 2018, during the Trump administration's first term, competitiveness has been at the heart of discussions. The SLGL region stands out as the most important in terms of economic integration. Benefiting from historically close relations, Canada and the United States share a border that is recognised as one of the most secure and collaborative in the world, with C\$3.6 billion worth of goods and services exchanged every day¹.

However, during his first term (2017–2021), Trump unilaterally imposed 23% tariffs on Canadian steel and aluminium, citing national security concerns, which led to the renegotiation of NAFTA into CUSMA under significant political pressure. The second term, which began in 2025, marked a significant escalation: on 3 March 2025, Trump announced tariffs of 25% on all imported Canadian goods (10% for energy products), accompanied by threats to increase these tariffs to 35% for automobiles from 1 August if no agreement was reached. These measures reflect a desire to dominate trade leadership by imposing a balance of power, even on traditional allies.

This shift in bilateral relations between the two countries represents a significant challenge, given that their economic integration has been based on free trade for decades. Until last February, the average tariff rate applied to Canadian exports to the United States was around 0.1%, but it reached nearly 3% in July 2025. This increase marks a turning point, accompanied by US investigations

Figure 13 Implied US customs duties on all Canadian products



Source: Waugh (2025) based on data from the US Census Bureau (2023) and Federal Register (2025)

¹ According to Statistics Canada data, in 2024, trade in goods between Canada and the United States exceeded the \$1 trillion mark for the third consecutive year. The United States was the destination for 75.9% of Canada's total exports and the source of 62.2% of its total imports. This represents approximately C\$2.74 billion per day in trade in goods. Adding trade in services, which amounts to approximately C\$17.7 billion per month in exports and C\$18.1 billion in imports, the daily total trade in goods and services between the two countries is close to C\$3.6 billion. For more information, visit: <https://www150.statcan.gc.ca/n1/daily-quotidien/250205/dq250205a-eng.htm>

into the effect of imports on national security. These investigations concern aluminium, steel, copper, timber, pharmaceuticals, vehicles, aircraft, drones, engines and semiconductors, among other products. This situation creates considerable uncertainty for cross-border trade and could weaken regional value chains that have long been structured around this privileged economic relationship.

Canada is responding to these actions. On 12 March 2025, Ottawa imposed counter-tariffs of approximately CAD 30 billion on US products – steel, aluminium and manufactured goods – on a “dollar for dollar” basis. These measures come amid tense diplomatic relations, with the US threatening to increase tariffs to 35% according to an ultimatum set for 1 August 2025. The prospects for peaceful trade are thus severely compromised. Obviously, the shock on the Canadian side is incomparable. While global trade was already struggling to recover from the effects of the pandemic on supply chains, and geopolitical turmoil in the Middle East, the Red Sea and Europe was increasing risks and uncertainty, as well as driving up transport and commodity prices, the trade war with a neighbour that seemed to be a sure thing has come as a blow to public and private actors, who see it as a further blow to Canadian productivity.

However, the report by Deslauriers et al. (2025)², puts the effects of the trade war into perspective, pointing out that “even if we consider a complete removal of regulatory barriers in the country, it would be utopian to hope for a 6.9% increase in the standard of living” (Deslauriers et al., 2025, p.6) . In other words, notwithstanding trade issues with the United States, Canada already has significant structural problems that limit its productivity. The authors also note that “even by addressing the harmonisation of provincial regulations—the real issue—the effect on the volume of east-west trade will remain limited,”

2 Deslauriers, Jonathan, Robert Gagné and Jonathan Paré, Productivity: The Key to a Strong and Resilient Domestic Market , Centre for Productivity and Prosperity (CPP) – Walter J. Somers Foundation, HEC Montréal, May 2025

because the distance between regional markets and the inability of businesses to overcome the effects of distance further widens the structural productivity gap. This puts into perspective the opportunities presented by Canada’s domestic trade strategy.

Structural challenges for maritime traffic

The SLGL corridor transport network faces several challenges due to its unique characteristics (Slack & Comtois, 2022). In particular, the specialisation in bulk cargo transport for large industrial companies – typical of the SLGL region – requires larger vessels than those found in other inland waterways. Lock management, interactions with public stakeholders, harsh winters that force the interruption of navigation seasons, and the complexity of the intermodal network are all factors specific to this region that add to the complexity of the system (Slack & Comtois, 2022). However, the competitiveness of many industries in the region on global markets depends on the capacity and performance of its multimodal freight transport network.

In Canada, the committee established in 2023 by the House of Commons highlighted several structural issues related to the expansion and optimisation of port infrastructure in Canada, as expressed by representatives of port authorities across the country (Montreal, Halifax, St. John’s, Hamilton and Prince Rupert). Among the obstacles mentioned were the slow project review process, debt ceilings deemed too restrictive for port authorities, and labour shortages in the maritime sector. Added to these constraints are tensions related to the coexistence of ports and local communities, which raise concerns about social acceptability. In response to these challenges, several witnesses called for better inter-port collaboration, including increased sharing of data on cargo flows and the implementation of an integrated national supply chain strategy. These findings underscore the need for a more

agile institutional and regulatory framework, as well as more coordinated governance across the Canadian port network³ (Standing Committee on Transport, Infrastructure and Communities, 2023).

Waiting times and intermodal congestion

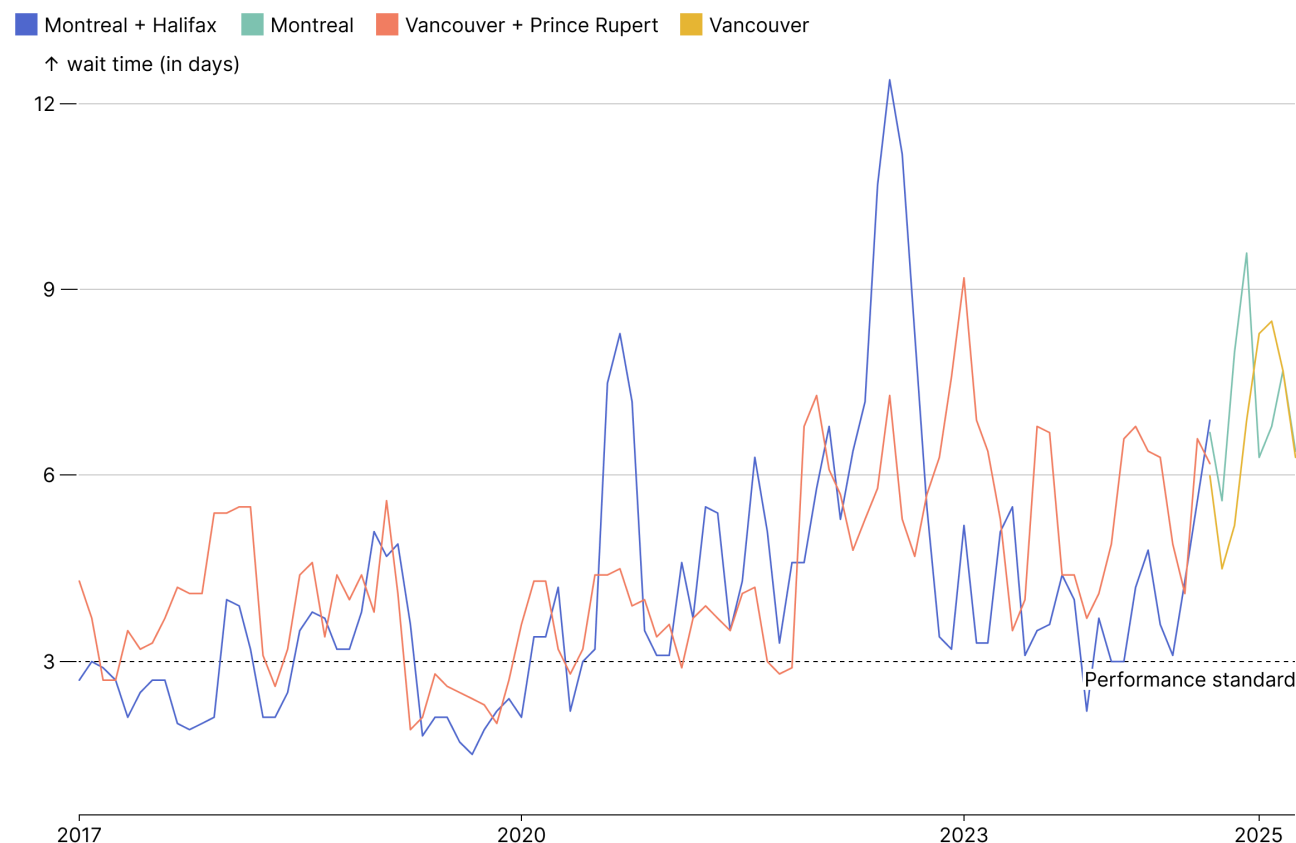
The smooth flow of goods between seaports and the hinterland also depends on good interconnectivity with land-based networks, particularly railways, which offer an economical and environmentally friendly alternative to road transport. However, poor sea-rail connectivity slows down the flow of goods and limits the overall capacity of ports (Abu-Aisha et al., 2024b). In Canada, the intermodal interface between ports and rail regularly faces bottlenecks that compromise the fluidity of maritime transport. Since the pandemic, container transfer wait times at the ports of Montreal and Vancouver

have far exceeded the three-day performance standard, reaching up to 12 days in Montreal in July 2022 and more than 9 days in Vancouver in January 2023. These delays are exacerbated by increased maritime traffic, work stoppages and weather events, revealing the vulnerability of port terminals to systemic disruptions. The persistence of these delays highlights the need for targeted investments in intermodal infrastructure, better coordination between port and rail stakeholders, and enhanced operational resilience to preserve Canada's commercial competitiveness (GVCdtLab, 2025a). Figure 14 based on Transport Canada's supply chain performance indicators for transport⁴ illustrates this increase in waiting times at Canadian ports between 2017 and 2025.²

³ To view these findings: https://publications.gc.ca/collections/collection_2023/parl/x27-1/XC27-1-1-441-14-fra.pdf

⁴ Indicators available at: https://www23.statcan.gc.ca/imdb/p3VD_f.pl?Function=getVD&TVD=1509026&CVD=1509032&CPV=12&CST=01012022&CLV=2&MLV=3

Figure 14 Increasing wait times at Canada's major container ports



Source: GVCdtLab analysis based on data from Transport Canada, Port of Montreal and Port of Vancouver

Limited private capital investment in Quebec and Ontario

Canadian port authorities (CPAs) must finance their maintenance and development through a combination of operating revenues, loans, private capital and public support, particularly from the federal government. The main federal programme, the National Trade Corridors Fund, has awarded approximately \$4.6 billion to various transport infrastructure projects since 2017 (Transport Canada, 2023). For a historical perspective on maritime infrastructure investment, Statistics Canada's Infrastructure Economic Account provides estimates of spending since 1981, but in a more limited scope restricted to physical assets such as ports, harbours, canals and waterways. Figure 15 shows the ratio of private to public investment in maritime infrastructure in British Columbia, Ontario and Quebec since 1981.

These data reveal regional contrasts: in Ontario, maritime investments come almost exclusively from public funds; in Quebec, private contributions exist but remain secondary; in British Columbia, on the other hand, private

capital plays a major role, regularly exceeding \$1 billion annually in recent years. Figure 16 shows that until the late 1990s, Ontario accounted for the majority of public investment, but this is now shifting more towards British Columbia. Quebec, for its part, has been investing around \$100 million per year since 2015, partly thanks to revenue from its ports. Despite these contributions, a deficit remains: the 17 APCs are planning approximately \$5 billion in capital expenditures between now and 2028, but are short \$1.24 billion, nearly a quarter of which is earmarked solely for the maintenance of existing infrastructure (CPCS, 2025). On the SLGL corridor, \$2.7 billion was invested in ports and terminals between 2018 and 2022, with an additional \$3.9 billion for the waterway. However, the majority of these funds came from the United States.

On the Canadian side, port investments total \$644 million (\$256 million in Ontario and \$388 million in Quebec), while all waterway-related expenditures (\$388 million) are concentrated in Ontario (Martin Associates, 2023b). On the American side, federal funding for ports comes mainly through two major programmes: the

Harbour Maintenance Tax Fund (HMTF) and the Port Infrastructure Development Programme (PIDP). Both programmes have seen significant growth in their allocations in recent years, particularly for Great Lakes ports. Since 2014, the HMTF has more than doubled to reach \$900 million in 2025, 13% of which is now reserved for Great Lakes ports. The PIDP has seen its annual budget double since 2021 thanks to the Infrastructure Investment and Jobs Act, reaching \$450 million. Between 2019 and 2023, thirteen Great

Figure 15 Annual public investment in maritime infrastructure

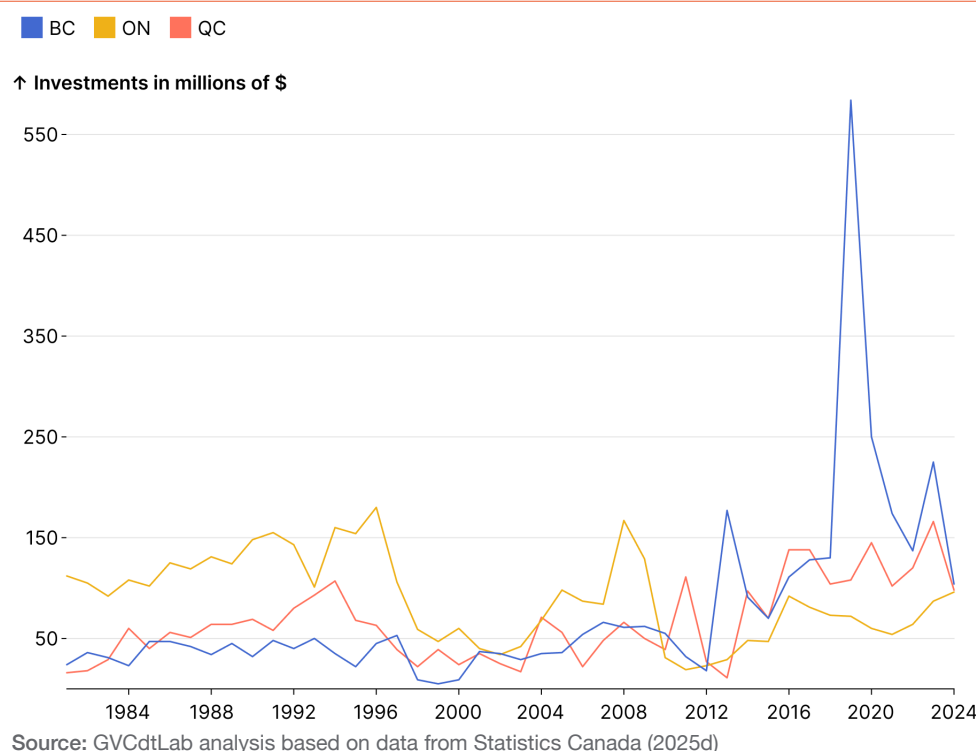
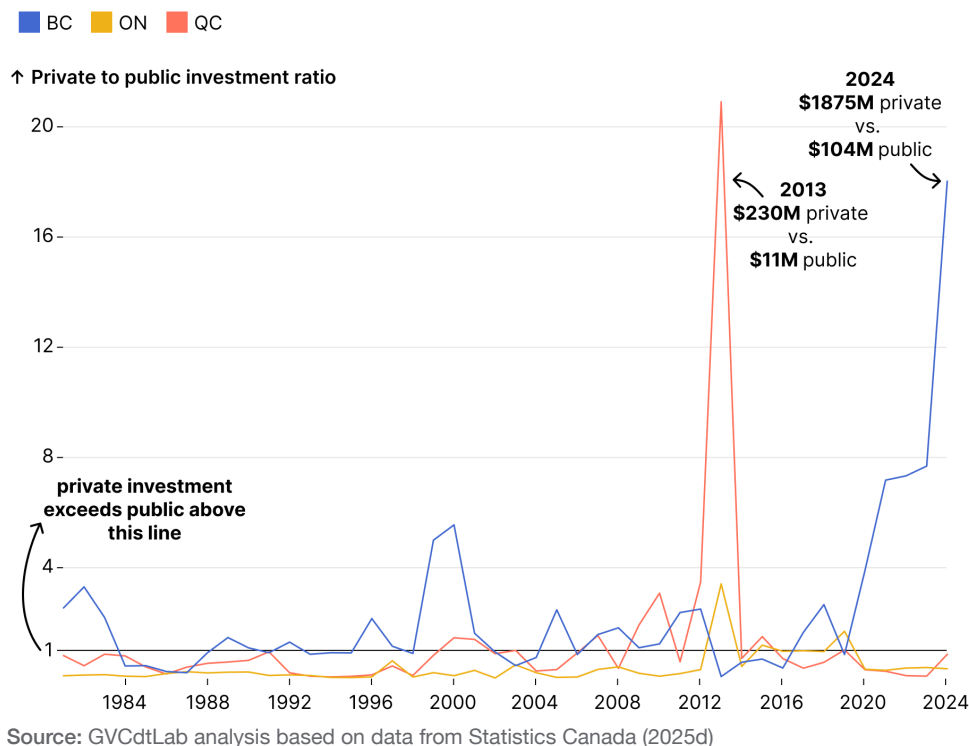


Figure 16 Private investment per dollar of public funding in marine infrastructure



Lakes ports have benefited from \$168.9 million from this programme. These developments reflect renewed federal interest in Great Lakes shipping and port infrastructure (American Great Lakes Ports Association, 2023).

In summary, British Columbia is attracting more and more private capital, while Quebec and Ontario remain dependent on public funding. And at the SLGL system level, Canada lags behind the United States, a worrying gap for the future competitiveness of its maritime corridors, already weakened by ageing infrastructure and expected increases in demand.

Concentration of CBSA infrastructure for customs clearance

The Canada Border Services Agency (CBSA) plays a dual role in international trade: protecting the country by controlling the entry of prohibited goods and enforcing regulations, while facilitating Canada's competitiveness through efficient customs clearance procedures. These procedures vary depending on the nature of the goods, the mode of transport and the destination, resulting in parallel mechanisms that

are often complex and slow down the flow of trade. However, several current or potential points of entry could serve as multimodal hubs and offer greater flexibility to businesses.

The rules differ for exports and imports: most exports require only an advance electronic declaration, while those to the United States are exempt from CBSA authorization. Imports, on the other hand, must be released by the agency before entering the country. However, in 2014, less than 1% of CBSA employees were

assigned to export control, according to the latest report by the Auditor General on export control at the border (Office of the Auditor General of Canada, 2015).

With regard to maritime transport, only authorized ports of entry can process imports: ships must report to the CBSA at these ports. Of the 213 Canadian facilities, 79 are located in Quebec and Ontario (GVCdtLab, 2025f).

Although this figure probably only applies to containerised freight, the CBSA requires ships carrying foreign goods to Canada via the Great Lakes to call at Montreal for radiological inspection of containers (Canada Border Services Agency, 2023). On Canada's east coast, only the ports of Saint John, Halifax and Montreal have such equipment. This concentration of mandatory inspection infrastructure increases traffic and creates bottlenecks that might not otherwise exist. As reported by the Shipping Federation of Canada, ships often complete their customs clearance formalities at secondary ports rather than at their first port of arrival in Canada (Shipping Federation of Canada, 2024). This is particularly

noteworthy given that many of the authorized ports of entry mentioned above handle large volumes of bulk cargo.

Overall, Canada's marine customs clearance system is therefore concentrated in a limited number of ports and remains asymmetrical between imports and exports. Although most formalities are completed online, import clearance remains centralised and resource-intensive, increasing dependence on a few key points of entry at the expense of the network's capacity and resilience.

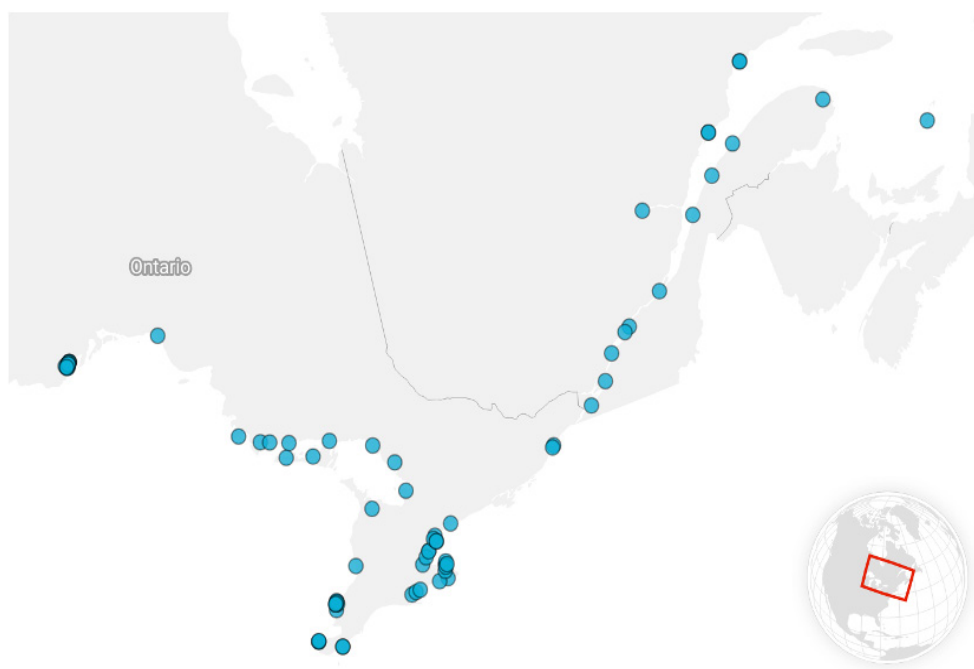
A multiplicity of stakeholders involved in trade and transport

On the Canadian side, the SLGL corridor is characterized by a multiplicity of stakeholders involved in trade and transport, including the Canadian and American governments (partments and agencies at various levels), port authorities, transport operators, shippers, riverside communities and industrial players, as well as universities and research centres. This diversity of actors, with varied and often

specific interests, illustrates the complexity of this regional ecosystem and creates significant challenges for decision-making, particularly due to the divergence of priorities and realities of each party.

At the institutional level, the management of the St. Lawrence Seaway involves multiple stakeholders and organizations. The Canadian and American governments share jurisdiction over the international section. On the Canadian side, various ministries and agencies have sectoral responsibilities: Transport Canada for marine safety and transport regulation, Fisheries and Oceans Canada for aquatic resource management and the Canadian Coast Guard, and Environment and Climate Change Canada for environmental issues. In Quebec and Ontario, provincial governments are involved in land use planning, the environment and the regional economy. Port authorities, for their part, play a major role in the development and administration of port facilities along the river, ensuring the operational management of maritime traffic, coordination with users and the development of infrastructure projects.

Figure 17 Maritime trade clearance system in Canada



C/VFSS: An authorized marine port of entry where cargo and commercial vessels report to the CBSA

Source: GVCdtLab analysis based on Canada Border Services Agency (2025)

II. Rethinking competitiveness in the 21st century for the SLGL region

Territorial competitiveness: An analysis based on Porter's diamond model

"A nation's competitiveness depends on the capacity of its industry to innovate and upgrade."
(Porter, 1990, The Competitive Advantage of Nations, p. 73)

The concept of **competitiveness** has been the subject of widespread debate in economics for several decades, precisely because of its polysemy and multiple uses (Lawrence, 2024). In its most common conception, it refers to the **ability of a country, region or organisation to maintain and improve its relative economic position** in the face of international competition, while ensuring sustainable growth in productivity and living standards.

However, as Porter (1990) pointed out, there is no single definition of national competitiveness, which can be understood either as the ability to gain market share, the ability to achieve greater internal efficiency, or the ability to create an environment conducive to innovation.

Porter proposes moving beyond strictly macroeconomic approaches to base the analysis of competitiveness on competitive advantage. His model identifies four interdependent factors:

- the quality of production factors

- (infrastructure, skills, technologies),
- the sophistication of domestic demand,
- the intensity of rivalry between local firms, and
- the presence of efficient related and supporting industries.

This framework highlights the importance of **territorial clusters** and local innovation dynamics. In this model, the state acts as a catalyst by creating an environment conducive to rivalry, investment and skills development.

Transformation of the production function in the age of data science

From an analytical perspective, **productivity** is the foundation of any discussion of competitiveness. Traditionally, it is measured using three components: labour productivity, often assessed by GDP per hour worked; **capital productivity**, measuring output per unit of physical capital employed; and **total factor productivity (TFP)**, which captures efficiency gains not attributable to an increase in traditional inputs (Hulten, 2001; Solow, 1956). TFP is particularly important because it reflects

the effects of technical progress, organisational innovations and skills development, all of which enable greater output to be produced with the same resources. According to Porter (1990), sustainable competitiveness depends precisely on the ability to continuously increase TFP.

From this perspective, the competitiveness of the SLGL corridor cannot be understood solely as a question of increasing gross capacity. It must be analysed in terms of **systemic productivity**, i.e. the ability to better coordinate and integrate the various modes of transport and the multiple public and private actors involved. Recent innovations in **data science, artificial intelligence and, in particular, the construction of digital twins** are opening up unprecedented opportunities in this regard. By enabling real-time modelling of freight flows, hydrological constraints and intermodal interactions, these tools help to increase the corridor's TFP by reducing inefficiencies, anticipating hazards (climate, congestion) and optimising the allocation of transport resources.

Thus, placing the issue of the competitiveness of the SLGL corridor within a rigorous theoretical framework highlights two essential points. **On one hand, the competitiveness of the region cannot be reduced to a static comparison of costs or volumes:** it fundamentally depends on the collective capacity to generate productivity through innovation, inter-institutional cooperation and logistical integration. **On the other hand, the corridor's future depends on its ability to adapt to the profound transformations in contemporary production, where data, algorithms and digital infrastructure are becoming inputs as strategic as capital and labour.**

Today, **recent advances in data science** are changing our ability to observe and model these phenomena. Access to massive, geolocated and disaggregated microdata makes it possible to accurately map specialisation trajectories, business networks, interactions between human capital (skills, know-how, training) and physical capital (infrastructure, equipment, technologies), as well as emerging forms of technological capital derived from data flows

themselves. This new granularity allows for empirical inferences that were previously out of reach and gives substance to measurable, contextualised and intelligently oriented competitiveness. They reveal the full complexity of the economy. Capital is no longer limited to physical equipment; it now includes digital infrastructure, interoperability systems and digital twins capable of continuously reporting on operations. Work, meanwhile, is enriched by human capital geared towards interaction with intelligent systems and capable of interpreting the results that emerge.

Innovation operates on several levels, through the introduction of new technologies (e.g. robotics, advanced software), but also through the transformation of organisational methods. In this sense, competitiveness is not limited to the technology available, but depends on how it is integrated, structured and implemented in a productive ecosystem.

Infrastructure (both physical and digital) is an essential prerequisite for this integration. Roads, ports, electricity grids, high-speed internet and data platforms are all factors that determine the fluidity of trade, the speed of information transmission and, therefore, the overall efficiency of the economic system. Aschauer (1990) has shown that public investment in infrastructure is positively correlated with aggregate productivity, in particular by reducing logistical bottlenecks and increasing the efficiency of supply chains.

The quality of digital infrastructure is no exception; today, it is becoming crucial for integrating new technologies and supporting organisational innovation. The emergence of massive data processing capabilities is profoundly changing the conditions for production, innovation and economic coordination. However, this shift depends on investment in R&D, the quality of infrastructure, the upskilling of economic actors and, above all, the availability of usable granular data.

For the SLGL region, characterised by both mature industrial sectors and entrepreneurial dynamism in technology hubs such as Toronto and Montreal, digital transformation and the

increased use of artificial intelligence represent an opportunity to renew its competitive advantage. For example, in St. Lawrence port logistics, the **implementation of a digital twin**—i.e., a real-time digital copy integrating all traffic, infrastructure, and other data—aims to optimise resource allocation and flow management through simulation, which will transform the way transport services are produced.

Similarly, **digital interoperability between different modes of transport** (road, rail, water) and actors (terminals, customs, shippers) would eliminate many current inefficiencies. In other words, the logistics production function would incorporate a new key factor: real-time data, coupled with AI, as an input to continuously guide the use of physical assets. This would result in a more efficient, flexible and resilient corridor, capable of instantly adjusting its operations in response to unforeseen events (peaks in demand, storms, incidents), where previously resources were wasted due to fragmented information and time lags in response.

Application of Porter's model to the SLGL corridor

Applied to the SLGL corridor, the theoretical framework is particularly illuminating. **This corridor, which is a critical infrastructure for North American trade, illustrates the tensions between traditional approaches to competitiveness, focused on the availability of physical infrastructure (ports, waterways, rail and road networks), and more contemporary approaches, which emphasise the integration of organisational and digital innovations.**

As mentioned in the previous section, Porter's diamond model is based on four main

determinants: the quality of production factors (infrastructure, skills, technologies), the strength of domestic demand, the intensity of rivalry among local firms, and the presence of efficient related and supporting industries.

In order to analyse the economic issues specific to the SLGL region, we identified its strengths and challenges, adapting the model to the specific characteristics of its ecosystem and selecting four determinants: production factors (infrastructure, skills, technologies), freight transport demand conditions, competition between logistics players and modes of transport, and the presence of related and supporting industries.

Factors of production (infrastructure, skills, technologies)

The SLGL corridor benefits from significant infrastructure capital: major ports (Montreal, Quebec City, Hamilton, Duluth, Cleveland), developed waterways (St. Lawrence Seaway), continental rail networks (CN, CP, CSX, Norfolk Southern, soon to be integrated into Union Pacific) and interconnected road networks. This network makes the corridor a unique multimodal hub.

Strengths:

- An integrated multimodal transport network directly connecting the industrial and agricultural basins of the Midwest to international markets.
- Energy and environmental efficiency of maritime transport: up to seven times more fuel-efficient than trucks (Chamber of Marine Commerce, 2023).
- Potential capacity in the St. Lawrence Seaway
- Massive investments in physical infrastructure on the American side, but less so on the Canadian side
- World-class research expertise and university training

Challenges:

- Structural constraints: Seawaymax size limit

An initial report on the strategic role in 2008

More than fifteen years ago, the IBI Group's 2008 report on the St. Lawrence–Great Lakes Trade Corridor⁵, already highlighted the strategic role of this transportation system for the North American economy and the need to adapt its infrastructure to the new realities of global trade. This report was written in a context marked by strong growth in global trade, the rise of containerised transport and the desire of the Canadian and American governments to strengthen the competitiveness of their logistics chains in the face of globalisation. At that time, several international corridors, such as the Pan-ama Canal and the Port of New York/New Jersey, were undergoing massive investment to adapt to the increase in ship size and new trade dynamics. The report sought to position the SLGL corridor as a credible and sustainable alternative, capable of attracting more traffic by exploiting its still available maritime capacity.

The study highlighted the corridor's strengths (proximity to major North American industrial and agricultural basins, the environmental advantage of maritime transport, a dense port and intermodal network) but also its structural weaknesses: the seasonality of the Seaway, lock size limitations, congestion at strategic passages (Detroit–Windsor, port access), and lack of recognition of the potential of short sea shipping. It called for a concerted strategy between public and private actors to modernise infrastructure, diversify flows and fully integrate the corridor into global logistics chains.

This report highlights issues that remain relevant today:

- Congestion in major urban centres and at border crossings, such as Detroit–

Windsor, has been partially addressed with the construction of the new Gordie Howe Bridge, scheduled to open in 2025–2026. However, road and rail congestion remains a persistent challenge.

- Similarly, the depth and size constraints of the Seaway locks have not changed: they still limit the size of ships and hinder the development of containerised flows. Added to this is the sea-seasonality of navigation: the three-month winter closure remains, offset in part by logistical solutions such as storage or rail, without solving the structural problem.
- Road and rail access to major ports has seen some improvements, particularly in Montreal with the expansion of terminals (Viau, Contrecoeur under construction). Nevertheless, pressure continues to mount with the increase in trucking.
- Montreal has established itself as a major container port on the east coast, but remains in direct competition with Halifax and New York/New Jersey. On the other hand, the development of regional short sea shipping remains marginal due to a lack of incentives and integration into logistics chains.
- Progress has been limited in terms of intermodal connections with the Midwest. Rail still dominates, but initiatives to improve flow are hampered by governance and competition issues.
- In terms of human resources, the shortage of skilled labour persists and is accompanied by an urgent need for generational renewal.
- Public perception of the maritime industry has improved somewhat, with greater emphasis on environmental benefits, but the sector remains largely absent from public debate compared to rail or road. Finally, public-private partnerships have multiplied to finance port and logistics projects, but coordination between Canadian and American players remains uneven.

This report also highlighted the corridor's delay in implementing certain technological innovations, while other regions of the world had undergone significant logistical transformations during the same period.

⁵ Groupe IBI, 2008, Étude sur le corridor de commerce Saint-Laurent–Grands Lacs, initiée par le Conseil du Corridor Saint-Laurent–Grands Lacs. Rapport disponible à ce lien : <http://www.bv.transports.gouv.qc.ca/mono/0988468.pdf>

(vessel size limit), seasonality of navigation (2- to 3-month winter closure).

- Rail and road congestion, particularly at the Detroit–Windsor crossing (hence the importance of the Gordie Howe Bridge, scheduled to open in 2025–2026).
- Waiting times and intermodal congestion at some container ports in Canada.
- Ageing infrastructure requiring significant investment to remain competitive with East Coast ports (New York/New Jersey, Halifax).
- An imbalance in investment in physical infrastructure on the Canadian side compared to the United States
- A shortage of skilled labour in advanced technologies, particularly in robotics, AI, automation, and advanced logistics
- Resistance to automation, particularly in container ports

Conditions of demand for freight transport (transport and trade)

Historically, the SLGL has met demand for solid bulk goods (iron ore, coal, grain, limestone) and liquid bulk goods (oil, chemicals). However, changes in global trade favour containerised transport and value-added goods, areas in which the corridor lags behind.

Strengths:

- Significant local industrial and agricultural demand, supported by the steel, automotive and agri-food value chains.
- Growing pressure from stakeholders for low-carbon logistics solutions, which favours maritime transport.
- The Port of Montreal, which has established itself as a major gateway for containers, with the Contrecoeur project (additional capacity of 1.15 million TEUs).

Challenges:

- Low share of the corridor in international containerised transport compared to East Coast ports.

- Persistent dependence on traditional bulk cargo, exposing the corridor to fluctuations in global markets.
- Limited perception of the strategic value of regional maritime transport (short sea shipping), which remains marginal despite its potential.

Competition between logistics players and modes of transport

The competitiveness of the SLGL is also shaped by competition between logistics operators, both inter-port and intermodal.

Strengths:

- Competition between ports (Montreal vs. Halifax, Cleveland vs. Chicago) stimulates innovation and investment.
- Increased rivalry with rail and truck transport, encouraging maritime players to position themselves on sustainability and reliability.
- Innovative initiatives, such as the use of digital twins, optimize port planning and value chain fluidity.

Challenges:

- Unequal competition: rail and road transport remain more flexible, particularly for just-in-time delivery.
- High costs associated with port infrastructure modernisation and digital transition.
- Strategic risks related to the reorganisation of North American railway companies (e.g. Union Pacific's proposed acquisition of Norfolk Southern and uncertainty about CSX's response).
- Siloed operations among logistics players, which hinder data sharing.

Related and supporting industries

The SLGL region benefits from its proximity to powerful industrial clusters: automotive (Ontario, Michigan, Ohio), steel (Hamilton, Cleveland), aluminium (Quebec), agri-food (Midwest). These clusters generate logistics flows supported by the presence of research and innovation centres in AI and data science.

Strengths:

- Technology and research ecosystems in Montreal, Toronto and Chicago capable of applying data science and AI to logistics.
- Support from research centres and specialised organisations (CIRANO, Great Lakes Commission, North American universities).
- Development of public-private partnerships (PPPs) to modernise certain port infrastructures.

Challenges:

- Complex institutional coordination between Canada and the United States, sometimes leading to policy fragmentation.
- Divergent priorities in public investment in physical (Quebec: maritime; Ontario: road) and digital capacities depending on jurisdiction, to the detriment of coordination and pooling of actions at the regional level.
- Poor development of short sea shipping due to a lack of regulatory or fiscal incentives.
- Persistent shortage of skilled labour in the port and logistics sectors.

Table 2 Porter's model applied to the SLGL region

Factor	Application to the SLGL corridor	Strengths	Challenges
Production factors (infrastructure, skills, technological capital)	Ports (Montreal, Quebec City, Hamilton, Duluth, etc.), Seaway, rail networks (CN, CP, CSX, NS, Union Pacific), road and airport networks.	Existing maritime infrastructure; proximity to major industrial/agricultural centres; energy efficiency of maritime transport; availability of multimodal infrastructure.	Size constraints (Seawaymax); seasonality of the Seaway; rail and road congestion (Detroit-Windsor, port access); aging infrastructure.
Demand conditions (domestic market requirements and sophistication)	Strong domestic demand for bulk commodities (iron ore, coal, grain) and manufactured goods; growth in Canada-US cross-border trade.	Growing demand for greener and more resilient supply chains; increased interest in coastal shipping and short sea shipping; pressure from industries for reliability and sustainability.	Low share of container transport in the corridor compared to East Coast ports; dependence on traditional bulk goods; limited public perception of the potential of maritime transport.
Rivalry between logistics players and modes of transport (competitive intensity, incentive to innovate)	Competition between ports (Montreal vs. Halifax vs. New York/New Jersey) and between modes of transport (maritime vs. rail/truck).	Rivalry that stimulates investment and innovation (e.g., port projects in Montreal and Contrecoeur); opportunity for differentiation through innovation digital (digital twins, AI).	Asymmetric competition with rail and truck, which are often more flexible; high adaptation costs to modernise maritime infrastructure.
Related and supporting industries (clusters, specialised services, R&D, innovation)	Presence of logistics, industrial and technological ecosystems (Toronto, Montreal, Chicago); universities, research centres	Regional clusters in automotive, steel, aluminium, agri-food; rise of digital technologies and AI applied to logistics.	Complex institutional coordination between Canada and the United States; lack of structured mechanisms to support short sea shipping; increased need for skilled labour.

The application of Porter's diamond model shows that the **SLGL corridor has considerable structural competitive advantages**, but suffers from a strategic exploitation deficit. Its competitiveness cannot be reduced to a comparison of costs or traditional macroeconomic indicators. It reflects a much broader dynamic, in which the capacity of the logistics and production system to **innovate and cooperate** plays a central role.

To strengthen the competitiveness of the SLGL region and exploit its opportunities, this diagnosis based on Porter's diamond applied to this territory must be put into perspective with the determinants of the production function of Solow's growth model (1956): **labour productivity, capital productivity and total factor productivity**.

It is in this context that the next section identifies and explores three interdependent pillars that structure and leverage this competitiveness: **productivity**, understood as the optimisation of logistics operations and the integration of innovation; **infrastructural robustness**, based on intermodality and the digitisation of physical and digital infrastructure; and finally, **environmental sustainability**, an essential condition for positioning the SLGL corridor as a model of low-emission logistics and a credible player in the transition to sustainable trade.

Perceptions of transport and trade stakeholders in the region

Several interviews were conducted with transport and trade stakeholders in the region (including rail, maritime, logistics and academic researchers). Most stakeholders agree that competitiveness depends more on reliability and fluidity than on speed. All recognise the need for a collective effort, bringing together all links in the logistics chain (ports, rail companies, road hauliers, warehouse operators and regulatory authorities) in order to anticipate fluctuations in flows, prevent congestion and better coordinate handling and transport to optimise resources. However, priorities differ: some favour better governance, while others focus on technical optimisation and the integration of new technologies (IT systems, automation, inclusion of new technologies). Nevertheless, all highlight a worrying gap between the current skills of the workforce and the sector's growing technological requirements.

Labour issues

Workforce renewal is a critical issue for ensuring the corridor's long-term performance. Several stakeholders point out that port, rail and logistics jobs suffer from an unattractive image, which hinders recruitment, while an ageing workforce and competition from more flexible or technological sectors exacerbate the challenge. To address this, some are focusing on employer responsibility—internal training, improved working conditions, attractive careers—while others are emphasising the role of government programmes, adapting curricula, subsidising specialized training and integrating more digital and environmental skills into programmes. Furthermore, while it is true that labour disputes are a constant sword of Damocles hanging over the Port of Montreal's activities, this reality is not shared by Ontario's ports, which are not

experiencing any particular disputes.

Governance issues

Several stakeholders believe that the letters patent of port authorities limit their ability to act on recruitment, training or strategic workforce development. Designed with a focus on infrastructure management, these legal frameworks take little account of current issues related to energy transition or technological integration. Added to this are institutional silos, the absence of a clear intergovernmental framework and the lack of real-time information-sharing mechanisms, which hinder integrated corridor planning. Finally, administrative complexity—redundant procedures, delays, and disparities between Canadian and American jurisdictions—slows decision-making and limits the ability of ports to develop cross-border or intermodal solutions.

Customs bottlenecks

At the same time, the flow of labour and logistics is sometimes compromised by delays at the Canada Border Services Agency (CBSA). Inspection and customs clearance procedures can create bottlenecks that undermine the predictability of operations. Some stakeholders suggest strengthening coordination between the CBSA and logistics operators, or even integrating digital solutions for pre-declaration and advance document processing to reduce these delays. All would like to see the CBSA as one of the agencies driving Canada's prosperity and competitiveness and hope that the agency will devote more resources to making customs operations smoother, faster, more automated and more digitised.

Innovation and collaboration: Two levers for improving the corridor's attractiveness and competitiveness

The challenges identified in the previous section can be overcome by activating two complementary levers: innovation and collaboration. When mobilised in a coordinated and sustained manner, these levers offer significant transformation opportunities for businesses and the entire logistics sector in the SLGL region.

The first lever is **innovation**, a key driver of modernisation and efficiency. This lever has several dimensions:

- the collection, sharing and exploitation of data, which is essential for informed decision-making. This data feeds digital twin platforms for more optimal logistics

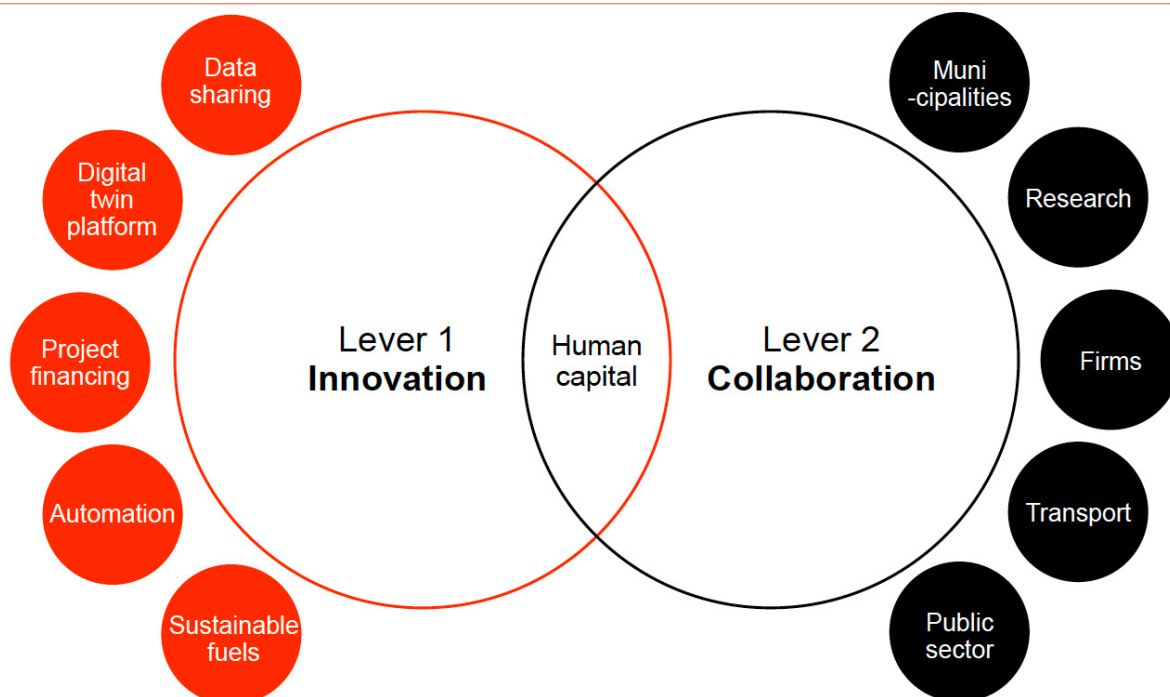
planning.

- automation, which enables the optimisation of operational processes in ports and multimodal platforms
- financing innovative projects, which is essential to support the implementation of technological solutions;
- the use of sustainable fuels, meeting the dual requirements of performance and environmental responsibility.

The second lever identified is **collaboration**. This requires municipalities, academia, businesses, transport operators (including transport support, logistics, etc.) and the public sector to work together. Innovation only bears fruit when it is supported by collaboration. Port electrification projects are a case in point, with their success depending on the joint mobilisation of cities, researchers and businesses.

At the heart of this is **human capital**, based on skills, expertise and talent. Investing in skills, training and attracting talent is therefore essential to fully exploit these two levers.

Figure 18 Two levers for enhancing attractiveness and competitiveness



III. Three priority pillars for the competitiveness of the SLGL region

Pillar 1 | Productivity

Productivity profile in the SLGL region

Despite its historical success, the SLGL region's economy is undergoing a transition, with the service sector accounting for a growing share of regional employment and economic activity, while manufacturing is becoming less and less important to the economy (Campbell et al., 2015). The region's economic activity is highly integrated and relies on complex supply chain networks that criss-cross the region, often regardless of borders.

Economically, the SLGL region has had to contend with the decline of the manufacturing sector observed since the early 2000s in advanced countries (Klier et al., 2005). The former industrial strongholds of the American Midwest and Ontario – sometimes referred to as the Rust Belt – have suffered from international manufacturing competition (particularly the rise of China) and the shift towards services. While some regional cities such as Toronto, Chicago and Montreal have been able to diversify their economies (finance, technology, business services), other areas are facing population decline and a shortage of skilled labour in high-tech industries. As in the past, the region's natural resources, particularly the Great Lakes themselves, continue to be important economic drivers. However, certain sectors such as

agriculture, heavy industry and transoceanic shipping have had a negative impact on the health of the Great Lakes (Campbell et al., 2015). The challenge is therefore to successfully transition to a knowledge-based economy by stimulating investment, technological entrepreneurship and the upskilling of the local workforce.

Productivity profile on the American side

However, the United States has recently seen an increase in labour productivity in the non-agricultural private sector and an increase in the number of hours worked, particularly in Indiana, which is recording the strongest growth with a 6.3% increase in productivity in 2024, followed by New Hampshire (+4.3%) and Maine (+4.1%). Since the pandemic, **labour productivity** in several port-based states has shown gains above or close to the national average, a sign of a recovery driven by investment in industrial logistics. Between 2019 and 2024, Illinois (+3.0%), Michigan (+3.6%), Minnesota (+3.5%), Wisconsin (+2.5%) and, above all, Indiana (+6.3%) will exceed or come close to the US average (+2.7%), while Ohio will see more moderate growth (+2.0%) (Bureau of Labour Statistics, 2025). These differences coincide with sector profiles and supply chains anchored in the SLGL network. Indiana also recorded production growth of +4.0% in the same year and benefits from a strong manufacturing sector with nearly 534,000 jobs and an equally significant logistics sector with nearly 168,000 jobs. The state also stands out for its significant investments in logistics and advanced manufacturing (AML) and Industry 4.0, supported by the *Indiana Economic Development Corporation* and the

Applied Research Institute (Conexus Indiana, 2023).

On the **western shore of Lake Michigan**, Indiana relies on a dense steel complex and ports such as Buffington–Indiana Harbor and Burns Harbor, which specialise in solid bulk cargo, particularly metal ores that are essential to the Midwest’s automotive supply chains. This industrial positioning, backed by robust port infrastructure, is consistent with recent productivity gains in the state. **Further north, the port of Duluth–Superior (MN/WI)** is the main point of exit for American iron ore, consolidating the regional steel chain, particularly for integrated steel mills and manufacturing activities. On the **southern shore of Lake Erie**, the ports of Cleveland (OH) and Toledo handle industrial bulk, steel and specialised containers, particularly to Europe, while the ports of Detroit and Monroe (MI) handle flows of petroleum products, chemicals and inputs for the automotive industry. In **Michigan**, the transformation of the automotive sector (electrification, battery chemistry) is leading to logistical reorganisations and industrial investments that support productivity. In **Minnesota and Wisconsin**, the iron and steel chain relies on advanced technical skills and adapted port capacities. In Illinois and Ohio, intermodal optimisation, boosted by rail hubs and river access, is stimulating demand for skills related to data management and network planning.

The US federal government has invested heavily in port modernisation. In 2024-2025, nearly **\$580 million** was allocated to 31 port improvement projects through the Port Infrastructure Development Programme (PIDP), aimed at enhancing the capacity, logistical reliability and environmental performance of Great Lakes ports. These investments promote more efficient distribution of goods, reduce costs and emissions, and strengthen the resilience of supply chains (U.S. Department of Transportation, 2024). At the local and regional levels, the state of Indiana, for example, is pursuing a long-term strategy with the *Conexus 2031 plan: Empowering Bold Industry Transformation*, which aims to strengthen

advanced industries (manufacturing, logistics) through educational connections, innovation centres and training tailored to digital technology and Industry 4.0 (Conexus Indiana, 2025a) .

In Cleveland, projects to electrify equipment, modernise terminals and improve rail access have been submitted in official files to MARAD (PIDP), illustrating the physical and digital upgrading of Great Lakes ports (electrical equipment, dock IT, integrated planning) (U.S. Department of Transportation, 2025a). At the regional level, the Federal Railroad Administration’s CRISI grants are explicitly aimed at modernising port rail connections, reducing bottlenecks and improving both safety and capacity in order to improve logistics flow and leverage productivity (U.S. Department of Transportation, 2025b).

Skills issues are becoming critical to transforming these infrastructures into productive performance. Conexus Indiana’s *Future Ready* report points out that although AML (Advanced Manufacturing & Logistics) **accounts for 25% of employment and 37% of the state’s GDP**, the main threat ahead is a **shortage of skilled labour**, particularly in robotics, AI, automation, and advanced logistics. Clearly, without a workforce capable of mastering new technologies, equipment remains underutilised. Conversely, a trained workforce multiplies the impact of physical capital (Conexus Indiana, 2025b) .

In terms of **digital capital**, the convergence towards flow management tools (real-time data, predictive planning systems, PCS, traceability) explains some of the recent gains in highly logistics-oriented states such as Illinois and, on the Michigan/Ohio side, the upstream-downstream synchronisation between manufacturing sites and port interfaces. These effects are visible in the value added by industry published by the BEA: the high shares of **manufacturing** (transport equipment in MI, chemicals/metals in IN/OH/WI) and the **growth of transport-warehousing services** in hub states confirm that productivity gains are concentrated where the infrastructure-data combination is most exploited. (U.S. Bureau of

Economic Analysis, 2025).

These productivity gains are achieved through the combination of (1) modernised **physical assets** (terminals, rail access, electrified machinery), (2) an operational **digital foundation** (integrated data, predictive planning), and (3) **human capital** aligned with these transformations. Recent federal data on productivity, value added by industry, and port performance converge: the regional competitiveness of the SLGL is indeed determined at the port-rail-industry interface, and states that invest simultaneously in these three areas of capital are transforming these expenditures into measurable productivity more quickly.

Throughout the Great Lakes region, productivity is growing, driven by advanced or high value-added industrial sectors such as pharmaceuticals, smart manufacturing and logistics, but it is in states with dense port infrastructure (Indiana, Illinois, Michigan) that the most significant gains are being seen (Ivy Tech Community College & TEconomy Partners, 2025; U.S. Bureau of Labor Statistics, 2025). These dynamics reveal a sectoral restructuring that is fuelled, on the one hand, by **physical capital** (modernisation of ports, specialised port equipment, enhanced intermodality) and, on the other hand, by **human capital**, through training, skills development and a sustained regional strategy. This dual dynamic is crucial to boosting **total factor productivity (TFP)**. By leveraging advanced technologies and intelligent sectoral coordination, these regions are able to combine efficiency, resilience and sustainable growth. This systemic approach is the most robust way to ensure their long-term competitiveness in terms of logistics, manufacturing and the environment.

Productivity profile in Quebec and Ontario

Transport support activities refer to all services provided by companies to facilitate the operation of various modes of transport, including port operations and cargo handling, services provided at railway stations, and loading, unloading and management of road terminals.

On the Canadian side of the region, over the 2019-2024 period, as indicated by Figure 19 and Figure 20, Quebec and Ontario present a convergent diagnosis: hourly wages have grown faster than labour productivity (real GDP per hour worked, 2017 chained dollars) in most of the transportation activities analysed. The gap is more pronounced in Ontario, where several segments combine sustained wage growth with sluggish or declining productivity, while in Quebec, a slight strengthening is expected in 2024, especially in maritime and road transport, without fully catching up with wages. This configuration puts pressure on unit labour costs and highlights the need for efficiency gains through organisational and technological investment.

From **2019 to 2024**, compensation is generally growing **faster** than productivity in Quebec, Ontario and Canada, suggesting upward pressure on unit labour costs, especially in **road transport and support services**. In rail, road, marine and support services, **labour productivity** (real GDP per hour, 2017 chain dollars) and **total hourly compensation** (wages + benefits per hour) do not always move in tandem.

In Quebec, **rail transport** is becoming more efficient (**+13% productivity**) while compensation is increasing even more (**+33%**), widening the gap. **Maritime transport** is progressing modestly (**+6.7% productivity**) with a marked increase in remuneration (**+22.4%**). **Road transport** is showing significant gains (**+16.5% productivity**) but remains behind remuneration (**+41.5%**). In **support services**, productivity is rising only slightly (**+6.1%**), while remuneration is climbing sharply (**+38.9%**). In other words, in Quebec, the two curves often rise together, but remuneration clearly exceeds productivity in all segments (Statistics Canada, 2025b).

In road transport, Quebec recorded a +16.5% increase in productivity (from \$29.7 to \$34.6 in 2017 dollars per hour) between 2019 and 2024, while remuneration rose by +41.5% (from \$24.9 to \$35.2 per hour). The recent trend is positive: between 2023 and 2024, productivity

Figure 19 Transportation support activities in Quebec: productivity and compensation

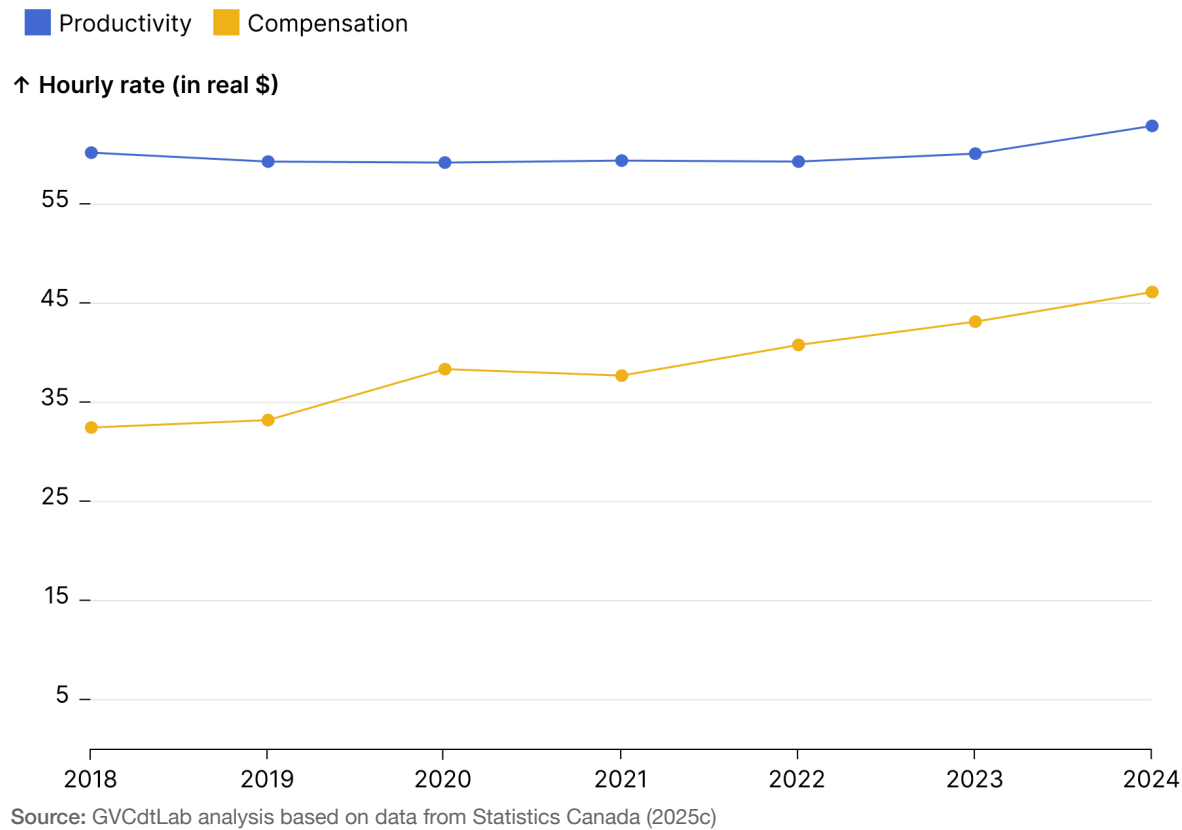
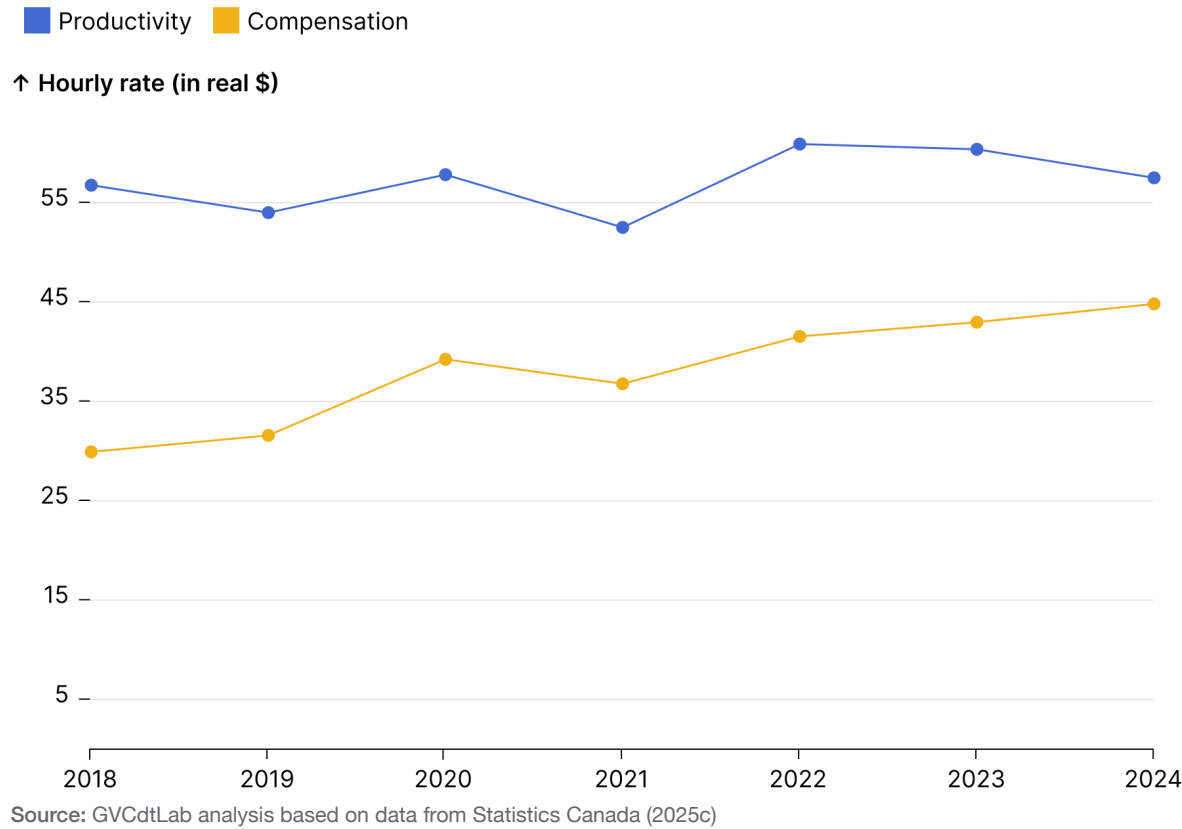


Figure 20 Transportation support activities in Ontario: productivity and remuneration



will increase by +3.6%. In Ontario, productivity will grow by +14.3% (from \$32.9 to \$37.6 in 2017 dollars per hour) over 2019-2024, while compensation will increase by +25.6% (from \$22.7 per hour to \$28.6 per hour). The very short term is also promising (+2.7% in 2023-2024), but the cumulative differential remains favourable to wages (Statistics Canada, 2025b).

In maritime transport, Quebec shows a productivity increase of +6.7% (from \$94.4 to \$100.7 2017/hour) over the entire period, while compensation increases by +22.4% (from \$48.8/hour to \$59.8/hour). The economic outlook is favourable for 2024, with productivity accelerating by +7.2% between 2023 and 2024. In Ontario, maritime productivity will increase by +10.4% (from \$63.6 to \$70.2 2017/hour) and compensation by +27.0% (from \$51.6/hour to \$65.6/hour). Here too, the last year is more positive (+3.7% in 2023-2024), without closing the gap between wages and productivity in the medium term (Statistics Canada, 2025b).

Rail transport shows contrasting provincial trends. In Quebec, productivity increases by +13.0% (from \$84.0 to \$94.9 2017/hour) between 2019 and 2024, while compensation increases by +33.0% (from \$51.8/hour to \$68.8/hour). However, there will be a decline between 2023 and 2024 (-3.0%) after these cumulative gains. Conversely, in Ontario, rail productivity will decrease by -22.6% (from \$136.0 to \$105.2 in 2017 dollars/hour), while compensation increases by +10.6% (from \$52.4/hour to \$57.9/hour), a particularly unfavourable configuration for unit costs (Statistics Canada, 2025b).

Finally, in transportation support services, Quebec recorded a measured increase in productivity of +6.1% (from \$59.3 to \$62.9 2017/hour) compared to compensation, which rose by +38.9% (from \$33.2/hour to \$46.1/hour). The profile in Ontario is similar: productivity increased by +6.1% (from \$54.3 to \$57.6 in 2017 dollars/hour) while compensation rose by +37.5% (from \$33.2/hour to \$45.6/hour), with a cyclical decline in productivity in 2023-2024 (-4.5%). In both provinces, this segment has a need for organisational improvement (coordination, safety, compliance, digitisation)

that has not yet produced efficiency gains commensurate with wage increases (Statistics Canada, 2025b).

In summary, the productivity-wage gap can be observed in both provinces—more so in Ontario (particularly in rail and support services). However, the signs for 2024 are more positive for maritime and road transport, especially in Quebec (Statistics Canada, 2025b).

In Quebec, the modernisation of the **Port of Montreal** is a cornerstone of regional productivity performance. In 2024, the port handled **35.41 million tonnes of cargo**, a level that remained virtually stable (+0.2%) compared to the previous year, thanks to investment in its infrastructure: in 2024, **\$74.8 million** was spent on strategic projects (Viau, internal railways, Contrecoeur expansion) (National Research Council Canada, 2025; Port of Montreal, 2025b). Transport Canada is supporting this momentum through the **National Trade Corridors Fund**, which is injecting more than **CAD 2.1 billion** into critical infrastructure until 2028, improving intermodality and the fluidity of logistics chains (Transport Canada, 2022).

The federal government is seeking to strengthen the competitiveness of the Quebec–Ontario corridor through sustained support for **logistics innovation**, the **digitisation of transport chains** and the **ecological transition**. The **National Supply Chain Office**, created in December 2023, coordinates these efforts, notably through a **supply chain digitisation programme** (Trade and Transportation Information System) to improve visibility, reduce bottlenecks and support real-time decision-making (Transport Canada, 2024).

Innovation for logistics efficiency

Port operations are central to the efficiency and competitiveness of global maritime supply chains. Suboptimal berth scheduling and inefficient allocation of quay cranes lead to increased vessel dwell times and terminal congestion. This terminal congestion spills over into related hinterland transportation systems, delaying the delivery of goods and increasing logistics costs (Natural Resources Canada, 2025).

In a competitive global environment, it is reasonable to expect that North American ports will need to continue to invest heavily in integrated planning systems, data-driven prediction models and simulation tools in order to optimise their operations and remain competitive. In this section, we review several operational aspects of goods transit in port terminals, from the arrival of ships to their loading onto other modes of transport, through optimisation models developed by research with a view to improving efficiency.

Models for optimising operations in container terminals

In container terminals, the coordination of cranes, berths, storage areas and vehicles is a key lever for reducing ship dwell times and streamlining flows. Academic and maritime industry literature presents a series of modelling approaches aimed at improving operational performance in the various dimensions of port activities.

- **Berth allocation and quay crane allocation:** Berth allocation is a major lever for improving port efficiency (Said et al., 2014). Machine learning applied to AIS data can predict docking times with over 98% accuracy (Zhai et al., 2022), supplemented by other recent work (Zhai et al., 2022; Rao et al., 2024). Beyond the allocation of docks and cranes, integrated approaches also combine storage area management and vehicle coordination. Kizilay et al. (2017) propose a comprehensive management model based on mathematical programming,

aimed at reducing turnaround times and increasing terminal throughput. Yu et al. (2024) extend this work by incorporating real-world constraints such as variable arrivals, tides and crane interference in order to simultaneously optimise quay utilisation and total ship turnaround time.

- **Vehicle management and container storage:** Container management in container terminal storage yards, where containers are temporarily stored before being loaded onto ships or picked up by lorries, is based on three key decisions: the allocation of storage locations, the deployment of yard cranes, and the management of internal traffic to avoid congestion. Jin et al. (2016)'s work shows that dealing with these aspects together reduces costs and overheads compared to sequential decisions. With automation, simultaneous coordination between autonomous vehicles (AGVs, ALVs) and storage areas becomes crucial; models (Hu et al., 2019) thus make it possible to optimise their use and limit operational conflicts. More recently, Feng et al. (2022) proposed a stochastic space allocation model that incorporates uncertainty and congestion, significantly reducing waiting times and improving logistics planning, confirming the importance of integrated and predictive approaches to increasing terminal efficiency.
- **Intermodal optimisation:** coordinated planning between maritime, road and rail transport limits bottlenecks. Dynamic models, such as that of Cahyono et al. (2022), integrate the activity of cranes, trucks and storage areas in real time in order to reduce inefficiencies and improve responsiveness to unforeseen events. Tested at the port of Jakarta, this model showed gains of 3 to 6% compared to current practices. For their part, Abu-Aisha et al. (2024a) demonstrate, based on the case of Trois-Rivières, that adjustments in modal share or rail frequency significantly improve fluidity and reduce blockages. This work confirms the value of combining optimisation and simulation to anticipate bottlenecks and strengthen the resilience of logistics chains.

Overall, the flexibility of these tools allows them to take into account various operational constraints, including labour availability, equipment limitations and arrival uncertainty. Simulation remains a powerful complement to optimisation, allowing terminal planners to test different policies and configurations in virtual environments. These simulations can not only validate the results of optimisation, but also provide insight into system bottlenecks and performance under stress scenarios.

Automation of crane and port vehicle

In 1967, when containerisation was still in its infancy, management consulting firm McKinsey predicted that most container ports would be automated within the next 50 years (McKinsey and Company, 1967). Forty years later, the same firm predicts even greater automation, with fully autonomous containers and vehicles in terminals (automated guided vehicles, AGVs) transporting containers to their inland distribution points. In this prediction, shipments are made just in time, on optimal routes and without waiting times (Saxon & Stone, 2017). While these projections paint an ideal picture of cargo supply chain management, they are still far from reality. At present, just over 4% of docks worldwide have adopted this technology, and most automated systems have only been deployed in container yards. Very few have automated transport between the quay and the yard, and at present, no terminal has fully automated quay cranes (Majoral et al., 2024; OECD - ITF, 2021).

Although automation is seen as a potential lever for efficiency, cost reduction and addressing labour issues, the results remain controversial. According to the International Transport Forum (2021) and Majoral et al. (2024), automated ports are not systematically more productive than conventional terminals and may even prove to be less efficient due to a lack of agility, despite lower costs for operators. And despite their rapid growth (62 automated terminals in 2023 compared to 53 in 2021), automated container terminals do not yet systematically outperform conventional terminals. Automated cranes achieve an average of 25 to 33 gross movements

per hour (GMPH), compared to around 35 in traditional ports, as illustrated by the case of the Maasvlakte II terminal in Rotterdam, whose productivity remains lower despite its complete automation. This shows that automation brings gains in consistency and safety, but remains limited by technological constraints (Majoral et al., 2024).

Nevertheless, there are compelling examples, such as the fully automated terminal in Qingdao, which achieved 43 movements per crane per hour in January 2020 (OECD - ITF, 2021) and an average of 36 GMPH with its quay cranes in 2022, which is above the usual standards (Majoral et al., 2024). This case illustrates the potential of advances in robotics, 5G, the Internet of Things (IoT), artificial intelligence (AI) and big data to overcome the current limitations of port automation (Majoral et al., 2024). However, this success must be viewed in the context of a broader Chinese national programme (Belt and Road Initiative, Greater Bay Area), which combines port modernisation with industrial and territorial development (Li et al., 2022; Ogawa & Tsuchiya, 2024). It thus illustrates that automation is only fully effective when it is part of a comprehensive and integrated strategy.

That said, although there is still no consensus on the positive effects of terminal automation on productivity (Kuehne Nagel & Lloyd's, 2025), the integration of smart technologies enabling real-time geolocation, continuous tracking, and better visualisation of collected data and operations seems not only essential but also necessary to face the future (Bakhsh et al., 2024). **It is therefore necessary to differentiate between data and robotics.** Automated data-related technologies are essential for improving visibility, refining projections and making informed decisions at all times. Automated robotics-related technologies, on the other hand, are not only costly but also currently lack agility and adaptability and pose tax revenue problems for local authorities.

Digital twins of port activities

Although the COVID-19 pandemic has greatly disrupted international trade, highlighting the

vulnerability of global supply chains and, in some cases, the precariousness of good neighbour agreements (Connolly, 2020; Scherer & Martell, 2020), it has also significantly accelerated the adoption of data-driven technologies in supply chain management, improving resilience and performance. Several scientific studies have documented this transformation, highlighting the central role of digitalisation in addressing the challenges posed by the pandemic (Moosavi et al., 2022; Raji et al., 2021; Zhao et al., 2023).

Digital twins provide a virtual representation of physical systems, enabling real-time simulation of logistics operations. The digital twin consists of different types of elements that form a framework for visually representing the entire life cycle of entities. This technology is set to evolve into an intelligent platform (Grieves, 2023). The digital twin is not limited to a one-off simulation: it relies on continuous, bidirectional data flows between physical and virtual systems, enabling dynamic optimisation, data-driven forecasting and real-time decision-making (Grieves, 2023; van der Valk et al., 2022).

Faced with growing traffic and environmental requirements, ports are looking to innovative technologies, such as sensor networks and digital twins, as levers to increase operational efficiency and strengthen their competitiveness (Klar et al., 2023). As the authors point out, these tools make it possible to collect real-time data on traffic and port activities, analyse different scenarios and automate certain operational decisions, reducing delays and errors. However, their adoption remains limited, especially in medium-sized ports, due to high initial costs, limited analytical capabilities, the complexity of integrating all operations into a single system, and concerns about data security and confidentiality. Furthermore, port use cases represent only a fraction of the potential offered by this technology, and it is essential to move beyond a localised view of the digital twin to adopt a systemic modelling of the entire supply chain (van der Valk et al., 2022).

That said, a few examples around the world are worth mentioning, such as the port of Busan (or Pusan) in South Korea, which has developed

a digital twin and AI to improve ship schedule planning and reduce carbon emissions through effective collaboration between maritime stakeholders (Eom et al., 2023). The Port of Singapore, one of the busiest in the world, is another example of the use of a digital twin combined with AI to simulate all of its port operations in real time.

Valuing and supporting the workforce for long-term competitiveness

Human capital and innovation: the intermediate driver

Once the infrastructure foundations are in place, human capital and innovation capacity become the key drivers for raising productivity. This involves training, attracting and retaining a skilled, adaptable workforce, as well as fostering a climate where innovation thrives (through universities, research centres, tax incentives for R&D, etc.). In the hierarchy of levers, human capital ranks below infrastructure, as its effectiveness depends in part on access to the tools and networks provided by that infrastructure – but it remains more decisive in the long term.

For the SLGL region, this means **investing in quality higher education, particularly in fields that are in demand** (engineering, computer science, supply chain management, artificial intelligence). The region is fortunate to have many leading universities (19 of the world's top 100 universities are located around the Great Lakes) and a significant pool of engineers and scientists. This asset must be capitalised on by strengthening programmes related to strategic sectors (e.g. marine engineering and logistics programmes to support innovation in transport, training in AI and data science). Highly skilled human capital has a double effect on productivity: direct (more productive workers individually) and indirect (they innovate, create businesses, improve processes, disseminate best practices). For example, introducing

multidisciplinary teams trained in cutting-edge methods in ports (optimisation engineers, industrial IT specialists) can enable a complete rethink of port organisation to increase efficiency.

Innovation, meanwhile, must be encouraged through a dynamic ecosystem. This includes support for innovative start-ups and SMEs, networking among stakeholders (cross-border clusters bringing together manufacturers, suppliers and research laboratories), and support for collaborative research projects focused on regional issues (smart transport, advanced materials for the automotive industry, bioeconomy linked to St. Lawrence resources, etc.) Already, innovative projects are emerging, such as the creation of a digital twin of the SLGL corridor involving HEC Montréal, Polytechnique, CIRANO and other partners, to model the regional economy and its flows. This type of initiative shows the way forward: by combining academic expertise and industrial needs, it is possible to produce tailor-made organisational and technological innovations that will greatly improve productivity (e.g., supply chain optimisation algorithms specific to the corridor's constraints, developed as part of the digital twin).

It should be noted that in this hierarchy, infrastructure and human capital/innovation interact strongly: infrastructure (including digital infrastructure) facilitates innovation (exchange of ideas, technology diffusion), while innovation can optimise the use of infrastructure (better coordination, predictive maintenance, etc.). Thus, the boundary between these levels is porous, and they must be developed in concert.

Adoption of artificial intelligence and retraining requirements

Rapid advances in artificial intelligence (AI) and digital technologies are forcing a profound reconfiguration of socio-economic models. In a context of global competition, governments are investing heavily in data and computing infrastructure, aware that technological leadership is now a decisive strategic lever. Pioneering countries—such as the United States, China and Japan—are setting the

standards, accelerating the capture of economic benefits and consolidating their position in the digital economy (Cayrat et al., 2021a; De Marcellis-Warin, 2022).

AI brings with it a positive productivity shock, which is likely to push back the frontiers of production, lead to reallocations between capital and labour, and profoundly transform sectoral and occupational structures (Li et al., 2022). However, its impact remains uncertain and asymmetrical. In advanced economies, around 60% of jobs are exposed to AI, mainly due to the predominance of cognitive tasks. A recent assessment indicates that, of these jobs, nearly half could suffer negative effects, while the other half could benefit from significant productivity gains (Li et al., 2022).

Unlike previous waves of automation, which mainly affected intermediate or low-skilled jobs, AI is challenging the security of highly skilled jobs. Advanced algorithms can now replace or augment tasks involving expert judgement, complex analysis or creative problem-solving, threatening professions previously considered safe from automation (Li et al., 2022). This dynamic increases the risk of labour market polarisation and amplified inequalities, both between professions and within sectors.

This transformation is particularly visible in sectors such as goods trading and maritime transport, where the transition to smart operations — integrating IoT, AI and blockchain — requires a fundamental rethinking of the skills required. To remain competitive, ports and logistics companies must invest heavily in continuing education programmes aimed at adapting workers' skills to new digital requirements (Adam et al., 2021). Without targeted retraining measures, digitalisation risks widening the gap between jobs that can be automated and those that require advanced cognitive or interpersonal skills (Gautié & Perez, 2024).

Pillar 2 | Physical and digital infrastructure

Infrastructure as an essential foundation for productivity

Infrastructure affects productivity in many ways, some direct and others indirect/externalities. Directly, new transport infrastructure (e.g. a motorway connecting two economic hubs) reduces the cost of transport between these hubs. This has a measurable effect on the productivity of businesses that use this road: they can deliver faster, reduce their inventories (thanks to more frequent deliveries), and access a larger labour pool (as employees can come from further away). Thus, even without changing their amount of capital or labour, these businesses produce more efficiently – a TFP gain.

Indirectly, infrastructure creates positive externalities: connecting new markets stimulates competition (forcing companies to become more efficient, which increases TFP through organisational improvement), enables economies of scale (a factory can serve a larger market, thus producing at a lower average cost, which is an aggregate efficiency gain), and facilitates technology diffusion (machines, ideas and methods circulate more when people and goods circulate more easily). Empirical studies, such as those by Brancaccio et al. (2024) on ports, confirm that well-targeted infrastructure investments lead to significant efficiency gains: in their study of American ports, they show that expanding the most congested ports significantly reduces ship waiting times and increases overall trade, including by reducing congestion in other ports that have not been expanded (thanks to traffic offloading). This result suggests a causal relationship: by removing a bottleneck, infrastructure investment improves the performance of the entire logistics system (thereby increasing the TFP of the transport sector).

Another causal channel is the reduction of intermediate costs: when reliable energy infrastructure is in place (e.g. a stable electricity grid), businesses experience fewer outages, use cheaper electricity than if they had to run individual generators, etc., which translates into higher TFP (fewer unaccounted losses in conventional inputs). Digital infrastructure is similar: broadband access gives businesses the opportunity to adopt digital tools that increase their efficiency (supply chain software, online recruitment platforms, etc.), which enhances TFP.

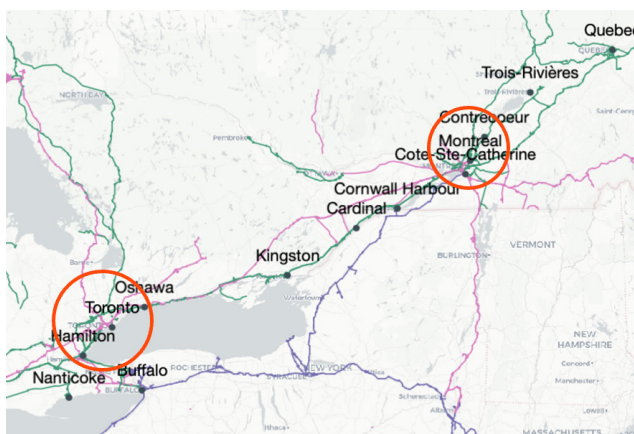
Of course, the literature points out that the marginal profitability of infrastructure decreases: building the first motorway brings a large TFP gain, but the tenth parallel motorway brings much less. There are therefore economies of scale in infrastructure and an optimum level of investment. But in the case of the SLGL corridor, there are still investments with high potential causal value, particularly for modernising/optimising existing infrastructure (we are talking more about infrastructure intelligence than simply quantity). For example, digitally networking all traffic lights in a city and connecting them to real-time traffic data can improve traffic flow without building a single new road – this is an urban PTF gain through smart infrastructure. We can therefore see that the way infrastructure is managed (agile, digital management) can itself become a causal factor in productivity.

Investing in intermodal transport capacity

Adopting a systemic and intermodal approach

In a context where more than 80% of international trade is transported by sea (UN Trade and Development, 2025), ports play a strategic role in the fluidity of trade and the control of commercial costs, but remain vulnerable to disruption. Faced with sustained growth in volumes and increasing pressure on existing capacities, it is essential to invest in

Figure 21 Main multimodal hubs in the region



the expansion and modernisation of physical infrastructure – quays, intermodal terminals, smart warehouses – in order to avoid or reduce bottlenecks and strengthen the resilience of port systems.

Infrastructure, whether physical (transport, energy) or digital (telecommunications, high-speed internet), is the material basis of productivity. Without reliable infrastructure, transaction costs skyrocket and factors of production cannot interact effectively. In the SLGL region, this translates into the critical importance of maintaining and modernising transport networks: cross-border roads and bridges for trucking, rail corridors, port facilities, St. Lawrence Seaway canals and locks, cargo airports, etc. Efficient transport infrastructure reduces transit times and logistics costs, enabling businesses to adopt more efficient production methods (just-in-time, centralisation of stocks, expansion of accessible markets) and thus increase their productivity. Similarly, energy infrastructure (reliable electricity grids, secure pipelines) ensures a stable supply of energy, which is essential for the continuous and optimal operation of factories and data centres.

The intermodal and integrated nature of infrastructure is a determining factor in a cross-border region such as the GLWS. A coordinated approach to infrastructure investment, rather than isolated decisions by jurisdiction, is necessary to avoid bottlenecks in the overall network. For example, if the St. Lawrence ports increase their capacity to accommodate post-Panamax ships but the inland rail network

remains outdated, potential port productivity gains will be lost to land congestion. Studies show that investing in one node of the network can have positive spillover effects on congestion at other connected nodes, hence the importance of a holistic view. The historical success of the SLGL corridor owes much to projects such as the St. Lawrence Seaway, which, at the time, was a massive, concerted investment between countries to provide the region with a first-rate logistics infrastructure. Today, this type of effort must continue: maintenance of key cross-border bridges (Ambassador, Blue Water, etc.), addition of railways or roads where demand exceeds capacity, development of intermodal zones (logistics platforms connecting rail, road and ship), etc.

Figure 21, a map illustrating the region's intermodality, is presented below. For clarity, the road network, which is almost omnipresent in the region, is not shown. It can be seen that current intermodal capacity remains heavily concentrated in the Montreal and Hamilton hubs. However, as part of a diversification strategy, the transport of bulk goods, particularly critical minerals, to new markets could significantly increase traffic passing through waterways.

The coordinated development of other ports in the region, viewed from a systemic transport perspective, would help alleviate congestion in these major intermodal hubs. A comparison of investments at the respective federal government level reveals a significant differential: in 2023, the US government invested an average of \$0.68 per tonne of cargo transported across all its ports, compared to \$0.48 per tonne for Canadian port authorities (CPAs), a difference of 40% (CPCS, 2025). Although this ratio does not distinguish between spending on existing infrastructure maintenance and spending on new projects, it nevertheless reflects a stronger public commitment in the United States. Furthermore, Canada's 17 CPAs are projecting total investments of approximately \$10 billion by 2040, including \$4 billion for maintaining existing infrastructure and \$6 billion for creating new facilities (CPCS, 2025).

Infrastructure and export potential

Looking at the critical minerals sector in the United States, it is unsurprising that Canada is one of the major sources of imports for many non-combustible minerals, with supply, processing and distribution organised into binational networks around the Great Lakes and the St. Lawrence River. The USGS's 2025 *Mineral Commodity Summaries* report confirms both the United States' structural dependence on imports for many minerals (cobalt, nickel, graphite, rare earths, aluminium, titanium, etc.) and Canada's central role as a supplier or processing partner for many of them, which places the SLGL at the heart of North American logistics routes (production, transshipment, metallurgy, export). The United States ranks **battery materials** (graphite, nickel, cobalt, lithium/manganese) at

the top of its priorities, ahead of alloy metals (niobium/titanium) and critical inputs for the agro-industry (potash). **Canada** is highlighted in official US-Canada discussions on mineral security and is a recurring theme **among major sources of imports**.

Bulk mining and industrial input flows in the region use a combination of maritime, river, rail and road transport, the efficiency of which directly affects unit costs and supply reliability. Upstream in Canada, rail (and, to a lesser extent, road) is the primary mode of transport from mining basins (Sudbury (ON), Saguenay & Laurentides (QC), Prairies for potash) to **port terminals** in the SLGL corridor.

The *Government Accountability Office* points out that the performance of the seaway and

Table 3 Modes of transport for critical minerals in the SLGL region

Critical mineral	Presence in the SLGL region (production/processing or transit)	Main mode of transport to the United States	Sources
Nickel	Production in Quebec (Voisey's Bay refined in Sudbury, transit via SLGL)	Maritime (bulk) + rail	NRCan (2023) Critical Minerals List; USGS (2024) Mineral Commodity Summaries
Cobalt	By-product of nickel/copper in Quebec and Ontario, processed in Sudbury	Maritime (bulk) + rail	NRCan (2023); USGS (2024)
Graphite	Mining project in Quebec (Knife Lake), possible transit via SLGL	Maritime (bulk)	NRCan (2023); Investissement Québec (2023)
Lithium	Projects in Quebec (Nemaska, North American Lithium), transit via SLGL	Maritime (containers and bulk)	NRCan (2023); Nemaska Lithium (2024)
Copper	Production in Ontario (Sudbury), transit via SLGL ports	Maritime (bulk) + rail	NRCan (2023); USGS (2024)
Aluminium (bauxite/aluminium oxide)	Production and processing in Quebec (Alma, Sept-Îles), shipment via SLGL	Maritime (bulk)	NRCan (2023); Alcoa Canada (2024)
Light rare earth elements	Exploration potential in Quebec, imports transiting through SLGL	Maritime (bulk or container)	NRCan (2023); USGS (2024)
Heavy rare earth elements	Limited exploration, imports transiting through SLGL	Maritime (bulk or container)	NRCan (2023); USGS (2024)
Zinc	Production in Ontario (Kidd Creek), transit via SLGL	Maritime (bulk)	NRCan (2023); Glencore Canada (2024)
Titanium	Production in Quebec (Sorel-Tracy), export via SLGL	Maritime (bulk)	NRCan (2023); Rio Tinto Iron and Titanium (2024)

Source: Ressources naturelles (2024)

intermodal connections influences volumes and costs in the region, and that maintenance and modernisation of navigation and land access assets are key determinants of regional competitiveness. In other words, bottlenecks cannot be resolved on a country-by-country basis, but at the level of the **integrated corridor** (United States Government Accountability Office, 2018).

Major current expansion projects and financing

Transport Canada allocates funding primarily to the stewardship and operation of infrastructure under its mandate. In its 2017 *Analysis of Programs and Subprograms by Strategic Outcome*, Transport Canada reported total actual expenditures of \$231 million allocated to the “Maritime Transportation Infrastructure” subprogram and approximately \$100 million to the “Land and Intermodal Transportation Infrastructure” subprogram (Transport Canada, 2017).

In addition, through the National Trade Corridors Fund (NTCF) program, which aims to improve the flow of domestic and international trade, \$4.1 billion in support for strategic infrastructure projects across Canada has been invested since 2017, including ports, airports, rail networks, logistics facilities and access roads. Furthermore, as part of a shift towards the digitisation of supply chains, a call for proposals launched in February 2023 targets digital infrastructure projects. As such, \$51.2 million in funding was announced in May 2024 to support 19 projects aimed at increasing the efficiency and reliability of Canada’s transportation system (Transport Canada, 2024b).

On the American side, funding in the Great Lakes region has intensified over the past decade. Notable initiatives include additional funding from the Water Resources Development Act (WRDA) and the Great Lakes Restoration Initiative (GLRI). The WRDA is revised approximately every two years and, since 2020, includes a provision ensuring that the Great Lakes region receives increased investment. Specifically, the Act stipulates that at least 13% of the annual expenditure of the Harbour

Maintenance Trust Fund must be devoted to maintenance projects in the Great Lakes navigation system (American Great Lakes Ports Association, 2023). The second programme, dedicated exclusively to Great Lakes ports, has provided more than US\$300 million in annual funding since 2010 (Great Lakes Restoration, 2025).

In addition, US\$17 billion has also been invested in ports and waterways in the United States through the Infrastructure Investment and Jobs Act of 2021. This legislation has nearly doubled funding for the Port Infrastructure Development Programme (PIDP) from an annual average of US\$245 million to US\$450 million. However, Great Lakes ports accounted for only 8% of the funds allocated between 2019 and 2023. Similarly, ports received US\$3 billion in funding for the acquisition of zero-emission port equipment and technologies through the Inflation Reduction Act of 2022 (American Great Lakes Ports Association, 2025).

The profitability of these massive investments is therefore becoming crucial, particularly in an economic environment marked by instability and uncertainty. On this issue, Brancaccio et al. (2024) propose an empirical framework combining queueing theory and demand estimation to assess the profitability of port investments in a volatile economic context. From their analysis based on port production function, port demand and port infrastructure costs, with an application to US ports, three main findings can be drawn. First, the benefit of investments depends particularly on how they are targeted. Of the 51 American ports analysed by the authors, only 15 generate a positive net return. When well targeted, investments reduce congestion by an average of 4.1% and increase trade by 42%. Secondly, an investment in a given port leads to an average reduction of 0.6% in congestion in other ports, highlighting the importance of coordinated decision-making in order to optimise the overall effectiveness of investment choices. Thirdly, macroeconomic volatility has a positive effect on the profitability of investments in certain ports, and also alters their geographical distribution.

Table 4 Major port expansion projects in the SLGL region

Projects in progress	Description	Investments	Sources
Expansion of the Port of Montreal in Contrecoeur	The Contrecoeur terminal will have an annual capacity of 1.15 million containers, or 60 per cent of the Port of Montreal's capacity. It will be strategically connected to the CN rail network and Highway 30. Its commissioning, scheduled for 2029, will generate significant economic benefits, with nearly 6,500 jobs during construction and 1,100 permanent jobs thereafter.	\$130 million	(Port of Montreal, 2025a) (City of Contrecoeur, 2025)
Improved reliability and increased exports at the Port of Thunder Bay	As part of the National Trade Corridors Fund, an investment of up to \$6.7 million for the Port of Thunder Bay to redevelop the rail yard and increase the capacity of the Keefer Terminal.	\$6.7 million	(Transport Canada, 2024a)
Construction of the SucroCan refinery in Hamilton	Construction of Canada's largest sugar refinery at the Port of Hamilton, in collaboration with HOPA.	\$135 million	(Hamilton Oshawa Port Authority, 2024)
Construction and reconstruction of terminals in Trois-Rivières	The construction of the new Pier 16 and the reconstruction of Pier 17 will improve the flow of goods, reduce port congestion and increase the overall efficiency of the port.	\$87.1 million	(Transport Canada, 2025) (Port of Trois-Rivières, 2025)
Construction of a multi-user electric conveyor, development of a new cargo storage area and improvement of the Marcel-Dionne wharf in Saguenay	The Port of Saguenay will finance the construction of a multi-user electric conveyor and the modernisation of access routes and industrial infrastructure. It will also develop a new paved outdoor storage area and optimize the Marcel-Dionne wharf for oversized cargo.	\$250 million	(Saguenay Port Authority, 2024)
Construction of a second lock in Sault Ste. Marie	The locks in Sault Ste. Marie allow ships to navigate the 21-foot drop in the St. Mary's Falls Canal. More than 88% of the cargo tonnage transiting these locks through the Soo is restricted to the Poe Lock due to the size of the ships. The New Lock at the Soo project involves the construction of a second Poe-size lock.	\$2 billion	(U.S. Army Corps of Engineers, Detroit District, 2025) (Taylor, 2024)
Project to deepen the main federal channels of the Port of New York to -55 feet	A new feasibility study to deepen the main federal channels by an additional five feet (to -55 ft MLLW) was completed in December 2024, and environmental review and design work are still ongoing.	\$8.660 billion	(New York District, 2024)
Calumet River Bridge Rehabilitation	This project involves the restoration of four historic structures (the 92nd Street/Ewing Avenue, 95th Street, 100th Street and 106th Street bridges), which are essential to port operations and the transport of goods along the Illinois Waterway between Lake Michigan and the Gulf of Mexico.	\$200 million	(City of Chicago, 2023)

Data infrastructure for smart logistics and informed decisions

Digitisation of logistics chains

Technological advances are progressing at a rapid pace across the globe, prompting nations to rethink their socio-economic models and promote the development of data and AI infrastructure. Leadership in AI and data management has become crucial in a context where the most advanced countries are those that will reap the maximum economic benefits. As the implementation of certain technologies in the past (such as 4G) has shown, the pioneers are also the ones who set the rules of the game and ensure their competitiveness in a future that is more digital than ever. However, according to a 2019 Deloitte survey, only 31% of companies that have adopted AI consider their approach to be successful. This reality highlights the importance of developing a coherent strategy that links the integration of new technologies to the strengthening of skills (Cayrat et al., 2021b). Rapid advances in digital technologies and AI are forcing governments and stakeholders to rethink their socio-economic models and invest heavily in data infrastructure, as technological leadership is a strategic lever where pioneers set standards and consolidate their competitiveness in the digital economy (Cayrat et al., 2021a; De Marcellis-Warin, 2022).

In terms of supply chains, it is becoming essential for planners to have a clear understanding of intermodal logistics flows (truck, train, ship) using the available data. Intelligent Transport Systems (ITS) offer new tools for collecting a variety of data in real time, as in the case of the FRATIS system⁶, which optimises truck movements in ports. However, this data is often heterogeneous and complex to process. Mastering data science is therefore crucial to fully exploit the potential of ITS. Advanced data analysis can improve planning, reduce costs, optimise delivery routes and assess the impact of public policies (Huynh et al., 2017).

In Canada, the Final Report of the National

Supply Chain Task Force 2022 included among its eight recommendations the need to “digitise and create end-to-end visibility of the transport supply chain for efficiency, accountability, planning, investment and security”. This recommendation acknowledged Canada’s lag in supply chain digitisation, which is hampering its competitiveness. To address this, it called for the implementation of a national data strategy, supported by close collaboration between government and industry, to improve the visibility, resilience and responsiveness of the system, while facilitating better-informed responses to disruptions (Gattuso et al., 2022)⁷.

Building a data science architecture

Technological developments related to data science invite us to rethink our very conception of productivity and move beyond traditional ideas. It is also important to distinguish between data culture and the implementation of new methodologies involving AI, machine learning, deep learning, etc., and robotic automation, which, firstly, is heavily dependent on the data collected and represents a considerable cost for “hardware” technologies that may quickly become obsolete.

Convergence towards a regional architecture based on data science would not only improve the efficiency and visibility of flows, but also increase North American digital sovereignty. This requires the political will to pool skills, harmonise technical standards and create interconnected logistics zones where technologies serve competitiveness, security and sustainability. In order to reduce the vulnerability of logistics chains, North American governments should aim to consolidate policies that support data interoperability and the sharing of digital infrastructure (Dudoit, 2023b). In addition, a data-driven strategy optimises human resource allocation and streamlines the costs associated with integrating advanced technologies into the logistics sector, which poses labour challenges. The transition to digital systems

6 See: <https://www.itskrs.its.dot.gov/2016-I00736>

7 See: https://tc.canada.ca/sites/default/files/2022-10/rapport-groupe-travail-chaine-approvisionnement_2022.pdf

requires skills adaptation and worker retraining. Disruptive technologies can lead to changes in occupations, causing concern among employees and trade unions. These factors can slow down the adoption and implementation of new technologies, thereby affecting the sector's competitiveness. In this context, it is essential to develop change management and continuing education strategies to support workers in this technological transition. Close collaboration between public and private actors, including trade unions, is necessary to ensure the smooth adoption of technologies, minimise social disruption and maximise economic benefits.

As highlighted in Dudoit (2023a), collaborative data platforms provide a common framework for sharing, governing and leveraging logistics information; like the Digital Transport and Logistics Forum (DTLF) in Europe⁸, they are a model of multi-stakeholder interoperability. They aim to increase the efficiency and visibility of flows while strengthening digital sovereignty, guiding investment through data and supporting skills development through public-private coordination. To realise their potential, governance choices, technical interoperability standards and skills support mechanisms still need to be defined.

8 https://transport.ec.europa.eu/transport-themes/digital-transport-and-logistics-forum-dtlf_en

Pillar 3 | Resilience and sustainability

Making the SLGL corridor a vector for resilience

Strengthening skills and training the next generation

Sustainability cannot be reduced to decarbonisation alone, but also depends on the workforce. It also requires the workforce to continuously acquire new skills in order to promote the adoption of new technologies, such as the remote-controlled cranes mentioned above. Modernisation will require training and upskilling of port, road and rail workers in new technologies (automated cranes, digital inventory management, synchromodal logistics). Technical training and apprenticeship programmes, in partnership with colleges and trade unions, should accompany the roll-out of new infrastructure. Promoting maritime and logistics careers to younger generations and diversifying the talent pool will also be crucial.

Strengthening infrastructure against climate risks

The SLGL maritime corridor is a strategic infrastructure for North American trade, but it is particularly vulnerable to the effects of climate change. As highlighted in a report submitted to the Canadian Senate in November 2024, the decrease in ice cover in the Great Lakes and on the St. Lawrence Seaway is increasing shoreline erosion, posing a threat to waterfront infrastructure such as Routes 132 and 138, and increasing the maintenance costs of port facilities. In addition, the increasing frequency and intensity of extreme weather events are reducing the durability of structures, with precipitation that used to occur once every 100 years now occurring every 25 years. Overall, the authors conclude that “*Canada is not prepared to face and overcome the impact of climate change on its transportation systems, and therefore on its supply chains. Current efforts*

are scattered; there is no national coordination, no concrete plan and no predictable funding, yet there is an urgent need for action.” (Comité sénatorial permanent des transports et des communications, 2024)⁹.

Infrastructure must be built or adapted to cope with greater variability in water levels and extreme weather events, which are expected to intensify with climate change. For example, it may be necessary to raise or reinforce quays and breakwaters, as well as adapt operational plans to cope with more frequent storms.

Improving data exchange

Transport data, particularly maritime transport data, contains valuable macroeconomic information that is often overlooked by public decision-makers. Shackman & Ward (2023) have shown, for example, that freight rates, both domestic and maritime, are strong short-term macroeconomic indicators, with maritime freight even offering greater predictive power in the long term. This conclusion is in line with the analysis of Daniel Dagenais¹⁰, former Vice-President of Port Performance and Sustainable Development at the Port of Montreal, who argued that during the global COVID-19 crisis, supply chains had become a determining factor in Canada’s inflation rate. For the first time in the era of logistics efficiency, transport costs exceeded those of energy and resources, providing a real-time indicator of future inflation in the country. Commercial transport thus appears to be a strategic economic proxy, capable of providing valuable macroeconomic insights for public decision-making thanks to real-time geolocation data.

Data is therefore a far more crucial resource than the integration of new technological equipment, which itself depends on the data collected. Building a true data culture, capable of feeding into the development of new indicators adapted

to local realities, is emerging as a much more powerful lever for regional competitiveness. By developing advanced analytical tools and leveraging information from operational data, stakeholders in the Corridor can not only better understand the real benefits of new technologies, but also anticipate market developments and continuously adjust their practices. Investing in the ability to collect, structure and interpret data thus becomes a strategic choice, much more sustainable and valuable than simply acquiring equipment, however innovative it may be.

Involving local communities and First Nations

The intensification of goods flows can generate positive spin-offs in terms of jobs, including for riverside and indigenous communities. However, it also generates negative externalities, such as noise pollution and erosion, which can affect these same communities. Including the populations directly affected in discussions on increasing these flows is therefore essential to ensure that strengthening the resilience of supply chains benefits as many people as possible.

Environmental challenges of maritime transport in the SLGL region

Climate issues affecting the competitiveness of maritime corridors

Climate change is causing significant fluctuations in water levels in the Great Lakes and the St. Lawrence River. These changes in river dynamics create several challenges for maritime traffic, including the inability of ships to pass under bridges and increased difficulty in navigating against stronger currents, not to mention periods of low water, when ships must be lightened to avoid hitting the bottom of the channel. A regional study conducted in 2016 to assess the economic aspects of adapting to lower water levels in the St. Lawrence River due to climate change provided further insight into

9 To view the report: https://sencanada.ca/content/sen/committee/441/TRCM/Reports/TRCM_Climate-Infrastructure-Report_F.pdf

10 Full interview: https://youtu.be/1CvxW_W_Lsk?si=QulE-2jcZs2LEy3DB

the sensitivity of socio-economic activities to low water levels (Larrivée et al., 2016).

Such disruptions are likely to hamper the flow of goods, slow down international trade and negatively affect the activity of its main ports and the Quebec economy (Dudoit et al., 2021).

In the coming decades, the SLGL region will experience warmer temperatures, more extreme precipitation and reduced ice cover. By 2063, the average annual temperature in the basin is expected to increase by 1 to 3°C, and intense precipitation events are expected to intensify (Bartolai et al., 2015). In addition, water levels in the SLGL basin are also vulnerable to extreme weather conditions (Mortsch et al., 2000), exacerbating the impacts. This concern about the consequences of climate change on hydrological conditions in the SLGL waterway system (Boyer et al., 2010; MacKay & Seglenieks, 2013; Mailhot et al., 2019), and on the resulting navigation costs (Millerd, 1996, 2005, 2006) is not new and has been the subject of simulation-based studies for many years. In this regard, it is useful to refer to the study by (Comtois & Slack, 2016), who conducted a cost-benefit analysis to quantify the potential economic impacts of lower water levels in the

St. Lawrence River for six targeted sectors of activity, namely marine transport, boating and tourism, drinking water supply, hydroelectric power generation, ecological services and the value of waterfront properties.

Navigation periods

In recent years, global warming has had a significant impact on the navigation season on the Great Lakes, particularly on the section connecting Montreal to Lake Ontario and the Welland Canal. While it traditionally began in the spring with a ceremonial passage marking the resumption of maritime trade after the winter, the season now tends to be longer. This extension is attributed to milder winters and a decrease in ice cover on Lake Ontario, allowing ships to travel earlier in the spring and later in the autumn.

As indicated on the Figure 22, analysis of historical data between 2004 and today reveals an average extension of the navigation season of approximately 6.5 days. Although this gain may seem limited in the short term, its cumulative effect is potentially significant on the functioning of logistics chains. A longer season would increase the flexibility of supply chains,

limit congestion during peak periods and encourage a reorganisation of transport modes for certain goods. Furthermore, data on maximum annual ice cover since 1973 confirms this trend. A marked decline of more than 17 percentage points in the extent of ice on Lake Ontario has been observed, reducing the natural constraints that once limited navigation. Thus, milder winters are not simply temporary climatic

Figure 22 Navigation season of the Montreal-Lake Ontario section

The trend from 2004 to 2024 shows an average increase of 6.5 days in season length, adding about 8 hours of navigation time each year.



Source: GVCdtLab analysis based on data from the Great Lakes-St. Lawrence Seaway System

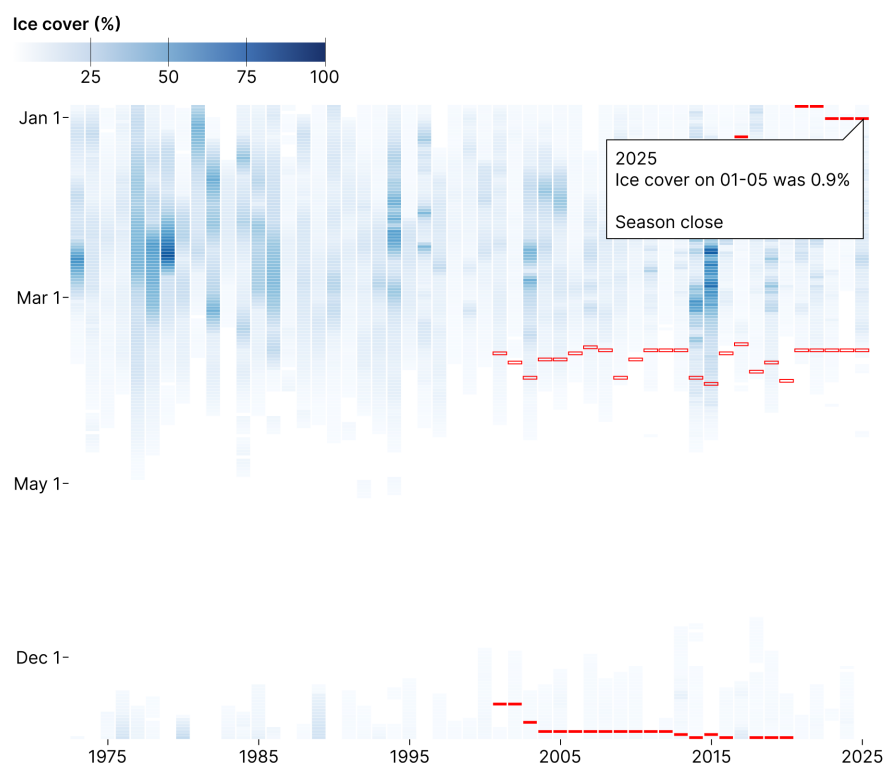
anomalies but a structural factor that is already transforming the commercial dynamics along this maritime corridor (GVCdtLab, 2025d).

Figure 23 indicates a decline in severe winters since the 1990s, leading to a significant reduction in ice cover on Lake Ontario. Despite this, the opening date of the navigation season has not been brought forward, and the extensions observed are mainly the result of later closures, leaving part of the early season unexploited. More flexible management of the schedule could make better use of this change, particularly for Canada, which would facilitate maritime exports from ports such as Hamilton and Toronto. In a tense geopolitical context, and in the face of milder winters, rethinking the organisation of this strategic trade route becomes all the more relevant (GVCdtLab, 2025e).

Greenhouse gas emissions in the St. Lawrence Seaway

Quantifying greenhouse gas emissions in the maritime sector is a methodological challenge, **given the diversity of vessel types, fuels used and segments of operation** (port manoeuvres, river navigation, offshore navigation). For the St. Lawrence Seaway, several studies have sought to provide an estimate of these emissions, while highlighting the existence of a significant margin of uncertainty (Comtois et al., 2024; Yaya & Lasserre, 2024). To a large extent, these emissions come from **the combustion of fossil fuels, mainly heavy fuel oil, marine diesel** and, in some cases, alternative fuels that are still marginal (liquefied natural gas, methanol, etc.). In addition to CO₂ emissions, there are also emissions of methane (CH₄) and nitrogen oxides (NO_x), as well as sulphur emissions (SO_x), which are subject to increasingly strict regulations, even though they are not greenhouse gases per se (Comtois et al., 2024).

Figure 23 Evolution of the period of maximum ice cover on Lake Ontario



Source: GVCdtLab analysis based on data from the Great Lakes-St. Lawrence Seaway System and the Great Lakes Environmental Research Laboratory

Commercial vessels transiting the St. Lawrence River fall into several categories: dry bulk carriers, oil tankers, chemical tankers, container ships, roll-on/roll-off ships, multipurpose cargo ships and cruise ships. Dry bulk carriers and oil tankers have historically accounted for the largest share of traffic, transporting grain, iron ore, coal and refined petroleum products, respectively (Landry, 2024). Container ships, although fewer in number, play a growing role in the regional economy, particularly for international flows of higher value-added goods. In addition, cruise ships travelling on the St. Lawrence, although seasonal, also contribute to emissions, especially during the peak tourist season in summer and autumn. The range of engines and technical standards is therefore wide,

which complicates the definition of a unified emissions profile.

A special feature of navigation on the St. Lawrence River concerns the winter ice periods, during which the Canadian Coast Guard conducts icebreaking operations to maintain the navigable waterway. These additional operations result in increased fuel consumption, both for icebreakers and for ships navigating in less than optimal conditions (Comtois et al., 2024; Marchand, 2024; Scalabrini, 2022). Engines often run at higher speeds and transit times may be longer, increasing overall energy consumption and, consequently, GHG emissions. At the same time, strict speed regulations in certain areas for safety or wildlife protection reasons (particularly whales in the St. Lawrence Estuary) can sometimes increase sailing time and alter emission profiles, depending on the type of vessel and its fuel consumption at low speeds.

Globally, international shipping is estimated to be responsible for 2-3% of global CO2 emissions (International Maritime Organisation, 2020). The specific share of the St. Lawrence Seaway remains difficult to determine precisely, but we do know that in Canada, emissions from the Canadian maritime sector have been estimated at 4.6 Mt of CO₂, or 3.0% of national transport-related emissions, marking a 9.7% increase compared to 2005 (Transport Canada 2023, p.52). Taking into account the various segments of the logistics chain (maritime transport, port handling, road or rail redistribution), the total carbon footprint associated with the Seaway is even greater. However, it should be noted that **maritime transport remains less polluting per tonne-kilometre than road or air transport, making it a relatively efficient mode of transport in terms of energy consumption** (Morandi et al., 2021; Transport Canada, 2023).

GHG emissions associated with the St. Lawrence Seaway are not evenly distributed throughout the corridor. Large port areas, such as Montreal, Quebec City, Trois-Rivières, Sept-Îles and the Ontario ports on the Great Lakes, account for a significant proportion of operations and, as a result, emissions related to

docking, departure and manoeuvring (Morandi et al., 2021). Loading and unloading activities, which often involve diesel-powered equipment, are also sources of emissions. In terms of sea or river operations, emissions depend on speed, the hydrodynamic characteristics of the vessel and the distance travelled.

It is important to note that the emissions inventories used for policy planning and setting reduction targets are sometimes based on criteria that do not always take international borders into account. For example, if a vessel transiting the St. Lawrence is flying a foreign flag, its emissions may be accounted for differently in national inventories. This statistical and methodological complexity makes the design and implementation of coordinated actions more difficult. In addition, the issue of sharing emissions among stakeholders (shipowners, charterers, port authorities, governments) remains a sensitive issue. Some believe that responsibility should lie primarily with shipping companies, while others argue for shared responsibility, taking into account the role of shippers and port infrastructure. These factors **highlight the need for greater harmonisation of emissions calculation methodologies, as well as increased collaboration between different jurisdictions to collect, analyse and share data.** The St. Lawrence port authorities have already undertaken initiatives in this direction, such as developing port-wide emissions inventories and implementing programmes to reduce air pollutant emissions.

Decarbonisation of maritime transport

Current regulations and initiatives

The decarbonisation of maritime transport has gradually become a priority in national and international climate change policies. At the international level, the International Maritime Organisation has played a catalytic role by adopting an initial strategy to reduce global maritime GHG emissions by at least 50%

by 2050, compared to 2008 levels (Comer & Sathiamoorthy, 2022; International Maritime Organisation, 2020). In 2021, the IMO adopted the proposed amendment adding to Chapter VI of the MARPOL Annex the requirement to use the Energy Efficiency Index, thereby introducing technical standards, assessed via the Energy Efficiency Design Index¹¹ (EEDI), and implementing operational measures such as the Ship Energy Efficiency Management Plan (SEEMP)¹² (Joung et al., 2020).

For the St. Lawrence Seaway specifically, Canada, as a signatory to the MARPOL Convention, applies Annex VI on the prevention of air pollution from ships. Since 2015, ships operating in Emission Control Areas (ECAs) must use fuels with a sulphur content limited to 0.1%. Although the St. Lawrence is not classified as an ECA for sulphur like the US coastal areas or the North Sea, Canada has harmonised certain standards to reduce sulphur and nitrogen oxide emissions (Morandi et al., 2021). This regulatory change has prompted several shipowners to switch to lower-sulphur fuels, although the impact on CO₂ emissions reduction remains partial.

At the national level, Transport Canada is running incentive and funding programmes to encourage innovation for a green transition in the maritime sector. One example is the *Environmentally Friendly Transportation Network Research and Development Programme*¹³, which aims to support research and knowledge sharing on clean energy, develop methods for measuring transport-related emissions,

and deploy clean technologies. The *Transport Innovation Support Programme*, linked to the *ecoTechnology Programme*¹⁴ for vehicles, the *Oceans Protection Plan*¹⁵, the *Quiet Ships Initiative*¹⁶ and the *Zero Emission Shipping Programme*¹⁷ are other examples of government measures supporting research and demonstration projects for technologies aimed at reducing the environmental footprint of ships, whether in terms of transport emissions, waste or underwater noise from vessels.

This desire to create synergies between programmes and other government initiatives should go some way towards meeting the need for a more comprehensive approach and thus partially address the issues of emissions linked to intermodality. As mentioned above, the assessment of emissions cannot be limited to the energy performance of the fuels used by ships alone. It must also take into account emissions associated with port infrastructure, land transport modes connected to ports (intermodality), and more broadly, the entire logistics chain. Such a more systemic approach is essential for measuring the energy efficiency of the maritime sector and guiding policies to reduce or offset emissions in a relevant manner.

Provincial governments, such as that of Quebec, have also implemented measures aimed at energy transition in transport. In 2018, under the auspices of the Ministry of Transport, Sustainable Mobility and Transport Electrification, the Quebec government implemented the 2030 *Sustainable Mobility Policy* (Gouvernement du Québec, 2018), including specific components for maritime transport. In 2023, the same ministry published an update on provincial government measures to promote the decarbonisation of the maritime industry, including some 20 programmes to support shore power connections, alternative fuels and research¹⁸. As part of Quebec's maritime

11 <https://www.imo.org/fr/MediaCentre/HotTopics/Pages/EEDI.aspx>

12 <https://www.imo.org/en/OurWork/Environment/Pages/Improving%20the%20energy%20efficiency%20of%20ships.aspx>

13 <https://tc.canada.ca/fr/programmes/programme-recherche-developpement-reseau-transport-respectueux-environnement>

14 <https://tc.canada.ca/fr/programmes/programme-ologie-hicules>

15 <https://tc.canada.ca/fr/campagnes/plan-protection-oceans>

16 <https://tc.canada.ca/fr/programmes/initiative-navires-silencieux>

17 <https://tc.canada.ca/fr/transport-routier/technologies-novatrices/vehicules-zero-emission/programme-camionnage-zero-emission>

18 https://www.transports.gouv.qc.ca/fr/ministere/role_ministere/colloques-congres-conferences/forum-concertation-transport-maritime/Documents/decarbonation-industrie-maritime-mesures.pdf

19 <https://tc.canada.ca/fr/programmes/programme-corridors-maritimes-verts>

strategy, *Avantage Saint-Laurent*, the provincial government has developed an action plan to promote the establishment of a smart economic corridor designed in particular to reduce the environmental footprint. Other programmes, more focused on trade corridors, exist at both the federal and provincial levels. This is the case with Transport Canada's *Green Marine Corridors Program*¹⁹, which provides funding for projects promoting the decarbonisation of the Great Lakes, St. Lawrence and Canadian West Coast networks, with one component targeting ports and another targeting ships.

Several ports along the St. Lawrence River have also launched initiatives to reduce their carbon footprint and encourage ships to opt for cleaner technologies. The Montreal Port Authority²⁰, for example, has implemented a green pricing programme that offers discounts on mooring fees for ships that meet certain environmental performance criteria, such as advanced EEDI certification or the use of low-sulphur fuels. Similarly, *cold ironing* facilities have been developed in some ports, allowing ships to shut down their auxiliary engines and connect to the shore-side electricity grid during dock operations, thereby reducing GHG and air pollutant emissions. However, the implementation of shore-side electrification requires significant investment in port infrastructure and assumes that ships are equipped to receive electrical power.

Electrification and alternative fuels

Reducing greenhouse gas (GHG) emissions places the decarbonisation of maritime transport at the heart of environmental, economic and technological challenges. This transition involves adopting new propulsion technologies, using fuels with a lower carbon footprint, improving energy efficiency and optimising port operations.

Several technological solutions are currently

being deployed or tested. Among them, **shore-side electrification** is an immediate lever for reducing emissions during port operations. Shore-side electrification, defined as the use of systems to supply electricity to ships during their port calls, is a promising technological solution for reducing GHG emissions in the maritime sector. Although these installations require significant investment, their potential for reducing local emissions and air pollution is recognised. In addition to the environmental benefits, this technology offers economic advantages for shipowners, particularly through reduced fuel and generator maintenance costs when used regularly. Internationally, the main electrified terminals are found in the cruise ship and large container ship sectors, i.e. those over 140 metres in length, due to their high energy demand when docked. On the other hand, few initiatives have been implemented for ships carrying solid or liquid bulk, general cargo, or smaller container ships, despite their significant environmental potential (Maritime Innovation, 2022).

In Quebec, this approach is particularly relevant given the renewable, clean and economical nature of locally produced hydroelectricity. However, despite these advantages, the adoption of shore-side electrification remains limited in Quebec's port infrastructure. The Port of Montreal stands out as a pioneer in shore-side electrification, being the only port in Quebec to offer this service to cruise ships at its cruise terminal. This system was implemented in 2017 as part of the rehabilitation of the Alexandra Pier, now known as the Grand Quay, and the cruise terminal (Maritime Innovation, 2022). The Port of Montreal has also introduced incentive pricing for ships using shore-side electricity, thereby reducing their dependence on auxiliary diesel engines (Morandi et al., 2021).

The Contrecoeur expansion project also plans to integrate this technology. It is estimated that in the initial phase, approximately 25% of the container ships docking there will have the necessary equipment to connect to the local power grid. In the rest of Quebec, shore-side electrification remains marginal. Apart from the port of Matane, the other main ports

20 <https://www.port-montreal.com/fr/le-port-de-montreal/nouvelles-et-evenements/nouvelles/carnet-de-bord/balise-electricite>

such as Sept-Îles, Port-Cartier, Baie-Comeau, Saguenay, Rimouski, Bécancour, Sorel, Gaspé and Port-Daniel do not have low or high voltage electrical connection infrastructure. Although some offer power supply for ship winterisation, this does not constitute an integrated shore-side electrification solution for regular operations (Innovation maritime, 2022). A technical challenge arises with the use of different electrical frequencies in different regions of the world. While North America and parts of Asia and the Middle East use a frequency of 60 Hz, the majority of other international ports operate at 50 Hz. To ensure compatibility, frequency converters must be installed, which entails significant additional costs for ports wishing to offer power supplies suitable for international ships. This lack of standardisation is an additional obstacle to widespread deployment. (Maritime Innovation, 2022).

In addition, the use of alternative fuels is growing rapidly. Liquefied natural gas (LNG) is currently the most widely used solution in Canada for short-term applications, particularly by the Société des traversiers du Québec (Comtois et al., 2024). However, fugitive methane emissions are sparking debate about the real long-term climate benefits of LNG (Yaya & Lasserre, 2024). More sustainable alternatives, such as methanol, green hydrogen or ammonia, are the subject of pilot projects but remain at a pre-commercial stage of development, with significant technical, economic and regulatory constraints (Landry, 2024). In the St. Lawrence Seaway, LNG has attracted particular attention because it significantly reduces sulphur and particulate emissions, while also partially reducing CO₂ emissions compared to heavy fuel oil (Comtois et al., 2024; Yaya & Lasserre, 2024). Some local service vessels and ferries have already made the switch. For example, the Société des traversiers du Québec has put LNG-powered vessels into service to serve the Lower St. Lawrence region (Comtois et al., 2024; Morandi et al., 2021). However, the large-scale adoption of LNG remains hampered by the cost of distribution infrastructure, fuel availability along the corridor, and still-limited GHG reduction performance in terms of fugitive methane emissions. Other solutions, such as hydrogen

or ammonia fuel cells, are attracting significant interest but remain at the development or demonstration stage, not yet allowing for mass commercial deployment (Landry, 2024).

In terms of research and innovation, collaborations between universities, research institutes and industry players are aimed at designing more efficient, lighter ships that are better suited to navigation conditions on the St. Lawrence River. Studies are focusing on the hydrodynamic optimisation of hulls to reduce water resistance (Y. Feng et al., 2025), on sail- or rotor-assisted propulsion (Kolodziejewski & Sosnowski, 2025), and on the use of artificial intelligence for optimised real-time navigation (Durlík et al., 2024). The fuel savings achieved through such optimisations, even if modest in percentage terms, can be significant when applied to an entire fleet (O'Brien et al., 2016). However, the complexity of the St. Lawrence, with its currents, tides and hazardous passages, requires detailed modelling and sophisticated navigation systems (Le Mouel et al., 2025; Matte et al., 2017). In addition, research projects must comply with a constantly evolving regulatory framework, which can delay the implementation of innovative solutions.

Issues related to decarbonisation

The decarbonisation of the St. Lawrence Seaway faces a series of complex challenges, reflecting the diversity of stakeholders involved, technical and financial constraints, and changes in markets and the regulatory framework. **Despite the progress already made, many questions remain open regarding the technological paths to be pursued, the financing methods to be mobilised, and the governance of the transition.** This observation requires that decarbonisation be considered from a systemic perspective, taking into account maritime, port, logistical, economic, and social aspects.

- A first challenge lies in the **technological and logistical complexity**. Several alternative fuels are attracting the interest of shipowners: LNG, methanol, hydrogen, ammonia and biofuels. LNG partially reduces GHG emissions but requires costly

infrastructure and carries a risk of fugitive methane emissions (Xing et al., 2021). Methanol can be produced from renewable sources, but its large-scale production remains limited and is highly dependent on the process used. Hydrogen and ammonia offer CO₂-free combustion, but pose challenges in terms of storage, transport and safety, while requiring carbon-free production to be effective (Atiodjia Njamen, 2025). **This plurality of technological pathways makes investment decisions uncertain and risks fragmenting the market, especially as the fleet must meet different operational needs (short-distance vessels, coastal shipping, ferries, large deep-sea oil tankers).**

- A second challenge is the **high financial costs associated with the energy transition in the maritime sector**. Modernising the fleet, converting existing ships or building new ships with alternative propulsion systems requires considerable sums of money that not all players can afford without public support. Returns on investment are also difficult to predict, as they are highly dependent on fuel price trends and the regulatory framework. Government funding programmes, where they exist, are often time-limited or targeted at pilot and research projects, leaving the question of large-scale deployment unresolved. Shipping companies are faced with the need to remain competitive with other corridors or modes of transport and are concerned about passing on additional costs to shippers, who may then opt for alternative routes or other logistics solutions.
- A third challenge concerns **multi-level governance and the coordination of public policies**. The St. Lawrence River falls under the jurisdiction of multiple entities on both the Canadian and American sides, and its status as an international commercial highway complicates regulatory harmonisation. The provinces of Quebec and Ontario, like certain American states, can adopt incentives or restrictive measures, but these initiatives sometimes remain

fragmented and face conflicting interests. The question of sharing the costs and benefits of decarbonisation also arises, both from a geographical perspective (which port or region finances the necessary infrastructure?) and from a sectoral perspective (which segments of the logistics chain bear the cost of the transition?). The lack of sufficiently integrated cross-border governance mechanisms, combined with the diversity of national and sub-national regulations, sometimes hinders the implementation of coherent and effective policies.

- A fourth challenge lies in the **social acceptance of decarbonisation and the mobilisation of stakeholders**. Communities living along the St. Lawrence River, maritime sector workers, environmental groups and First Nations have varied interests and expectations, ranging from preserving jobs and local economic development to protecting the environment and biodiversity. Although the energy transition presents opportunities for innovation and green growth, it can meet with resistance if it is perceived as jeopardising traditional activities or entailing additional costs. Consultation and cooperation processes are therefore crucial for defining shared objectives, assessing impacts and identifying acceptable compromises.

In this context, several prospects are emerging to strengthen the momentum for decarbonisation. First, technological innovation must be supported by university and partnership-based research in order to **improve the energy efficiency of ships, remove technical barriers to the use of alternative fuels and develop intelligent traffic and fuel consumption management systems**. Autonomous or semi-autonomous ships, although controversial in terms of safety, could ultimately optimise routes and reduce energy consumption, subject to appropriate regulatory oversight. Similarly, wind-assisted propulsion (rigid sails, Flettner rotors) or solar energy can complement the energy mix of certain ships.

Digital innovations for energy efficiency in the supply chain

Integrated supply chain planning and management can contribute to decarbonisation by optimising ship utilisation and reducing empty runs, port waiting times and congestion. Digital solutions, based on big data or AI, enable better synchronisation between the upstream and downstream parts of the chain, promoting greater efficiency. Smart ports are part of this trend: they use digital platforms to manage cargo flows, handling, ship parking and energy supply in order to limit downtime and unnecessary consumption.

Environmental competitiveness cannot be limited to fuel replacement alone. The overall energy efficiency of the maritime logistics chain is a major lever for reducing GHG emissions. With this in mind, **the modernisation of port equipment, the automation of processes and the optimisation of operations** are priorities identified at both the Canadian and Quebec levels. The deployment of IoT sensors for predictive maintenance, dynamic asset management and terminal energy regulation reduces energy losses and improves overall performance (Morandi et al., 2021).

Now, the integration of **digital twins** is another structural innovation. By simulating maritime operations in real time, these tools offer greater visibility on flows and enable faster and more accurate decision-making. Inspired by experiments conducted at the Port of Busan (Eom et al., 2023) and in Singapore, the ports of the St. Lawrence are beginning to explore their potential.

Finally, it should be remembered that energy efficiency cannot be isolated from the intermodal chain as a whole. A **systemic approach**, taking into account the interactions between maritime, rail, road and storage operations, is essential to ensure environmental consistency across the corridor. This is why several public programmes encourage logistics interconnection and energy conversion of equipment associated with all links in the chain (Government of Quebec, 2023).

Case study: Partial conversion to LNG and shore-side electrification in the maritime corridor

To better understand the reality of decarbonisation in the St. Lawrence Seaway, it is useful to examine a concrete example of a project led by a consortium of public and private actors. The case study is based on information gathered from various government and industry sources. **It involves a project combining the conversion of several bulk carriers to liquefied natural gas (LNG) and the implementation of shore-side electrification infrastructure in two major ports: Montreal and Quebec City.** Although this project does not represent all the initiatives carried out in the region, it illustrates some of the dynamics, constraints and opportunities specific to the maritime energy transition.

Context and objectives

Faced with increasingly stringent regulations on sulphur emissions and the prospect of carbon taxation, a group of shipowners specialising in dry and liquid bulk transport decided, in collaboration with the port authorities of Montreal and Quebec City, to invest in converting six existing vessels to dual fuel propulsion, i.e. capable of running on both LNG and marine diesel. The choice of LNG was motivated by a desire to comply with sulphur standards and partially reduce CO₂ emissions, while benefiting from financial support from federal and provincial innovation programmes. At the same time, the two ports have begun work to build or adapt LNG storage facilities and install shore-side electricity supply terminals, enabling ships to shut down their auxiliary engines during loading and unloading operations.

The primary objectives are to substantially reduce air pollutant emissions (SO_x, NO_x, fine particulates) and to reduce CO₂ emissions by approximately 20% compared to the use of heavy fuel oil, according to estimates by shipowners

and preliminary studies. Secondly, to meet regulatory requirements and avoid potential financial penalties in the future, particularly if a carbon tax or more restrictive measures were adopted at federal or international level. Finally, to improve the environmental image of the maritime corridor, in a context where customers and local communities are demanding greater responsible commitments from the sector.

Implementation and challenges encountered

The ongoing conversion of ships requires careful planning, as it involves major modifications to fuel tanks, propulsion systems and on-board safety systems. The shipyards involved in the operation had to mobilise a specialised workforce and go through a certification process with the maritime classification authorities. The tight schedule and additional costs associated with developing technical expertise have delayed the delivery of converted vessels. Furthermore, the installation of LNG storage and distribution infrastructure in ports has also encountered obstacles, particularly in terms of obtaining environmental permits and securing a regular supply of LNG. Port authorities had to negotiate with regional gas suppliers and ensure the safety of bunkering operations, an activity that is still not widespread on the St. Lawrence River.

With regard to shore-side electrification, the main challenge was the availability of electrical power and the capacity of the grid to support the additional demand. Investments were made to strengthen the ports' internal distribution networks and to negotiate a preferential rate with Hydro-Québec, on the grounds that the electricity produced in Québec is mainly renewable (hydroelectricity). Shipowners, for their part, had to equip their vessels with electrical connection devices compatible with

port standards, which generated additional costs. Finally, social acceptability was generally favourable, as the reduction in noise pollution and air pollution in port areas is viewed positively by local residents. However, some trade unions feared that the increasing automation of operations linked to port modernisation would result in job losses.

Preliminary results and lessons learned

Although it is still too early to draw a complete assessment, preliminary results indicate a significant reduction in SOx and NOx emissions for converted ships, as well as a decrease of approximately 15 to 20% in CO2 emissions, according to readings taken by shipowners and validated by third-party organisations. The use of shore-side electricity has also made it possible to almost entirely eliminate emissions from auxiliary engines during port calls, which represents a substantial gain in urban areas. However, the overall costs of the project have proved to be higher than initial estimates, due to technical uncertainties and delays in the supply chain. Some shipowners have expressed their intention to evaluate alternative options, such as biomethanol or green methanol, for future projects, believing that LNG may prove insufficient in the medium term to meet more ambitious decarbonisation targets.

In terms of governance, the project highlighted the **need for close cooperation between the various port authorities, Transport Canada, provincial governments and private companies**. The establishment of a steering committee, bringing together stakeholders on a regular basis, facilitated the resolution of practical problems and the dissemination of information. It also made it possible to involve local actors in the decision-making process, particularly through advisory committees. This approach could serve as a model for other decarbonisation initiatives on the St. Lawrence River, provided that the composition and operating procedures of the committees are adapted to the specificities of each project.

This case study shows that decarbonising maritime transport is not a linear process, free of difficulties. Stakeholders must contend with technological uncertainty, regulatory complexity, financial constraints and the need for multi-level coordination. Nevertheless, the experience gained and the progress made point to the feasibility, albeit partial, of a transition to less carbon-intensive modes of transport. However, the solutions implemented, whether conversion to LNG or shore-side electrification, cannot be the only answer to the problem of GHG emissions in the long term. They must be combined with other measures, or even replaced in the long term by more radical solutions if we are to achieve carbon neutrality by mid-century. This reflection brings us to the general conclusion of our article, which highlights the importance of a comprehensive approach tailored to the specific characteristics of the St. Lawrence.

IV. Drawing inspiration from European corridors

Enhancing the attractiveness and competitiveness of the SLGL corridor relies above all on efficient and innovative multimodal transport systems, supported by close collaboration between all trade and transport stakeholders. It is essential that networks be viewed as an integrated system, where each link counts, in order to identify each one's strengths and create opportunities for collaboration beyond institutional or sectoral silos. With this in mind, the development of the corridor requires a coherent and comprehensive multimodal vision, based on modern and coordinated infrastructure planning. Digital integration and an inclusive governance model are also key elements in optimising the corridor's operation and strengthening its competitiveness.

Europe offers useful lessons for the SLGL region, notably through its Trans-European Transport Network Policy, which promotes the integration of multimodal networks at the level of cross-border corridors, as well as through the implementation of the concept of synchromodality in its major logistics hubs, such as the port of Rotterdam in the Netherlands. Much more than simple transshipment points where cargo is exchanged, these hubs are truly integrated multimodal ecosystems, structured around close collaboration between public and private actors and innovation-oriented governance.

Integrated trade and transport corridors

Trans-European Transport Network (TEN-T) policy

In Europe, the Trans-European Transport Network (TEN-T) policy is an infrastructure development programme set up by the European Union and established by Regulation (EU) 2024/1679²¹. It aims to establish a coherent and efficient transport network across the continent, prioritising multimodal integration and the elimination of cross-border bottlenecks through unified work plans and dedicated coordinators.

This policy encompasses rail, road, inland waterway and short sea shipping networks, connecting ports, airports, terminals and urban centres, with the objectives of enhancing the mobility of people and goods, supporting trade and economic growth, and promoting social and territorial cohesion.

In particular, it provides that:

- By 2040, passenger rail lines in the core and extended network will allow trains to travel at 160 km/h or more, while the European signalling system (ERTMS) will be deployed across the entire network, replacing national systems to improve safety and efficiency.

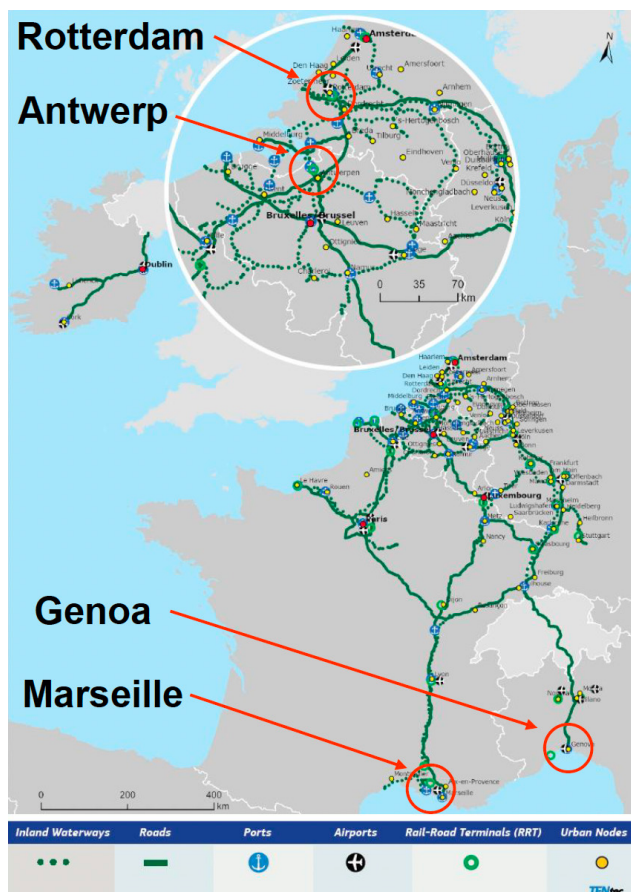
²¹ To consult Regulation (EU) 2024/1679 of the European Parliament and of the Council: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32024R1679>

- Major airports with more than 12 million passengers per year will be connected to long-distance rail, offering a competitive alternative to domestic flights. The number and capacity of freight terminals will be increased to accommodate 740-metre trains and promote sustainable combined transport.
- All major cities along the network are developing sustainable urban mobility plans to promote low- or zero-emission travel. The TEN-T network will also serve as a basis for recharging and refuelling points for alternative fuels, such as hydrogen, complementing the regulation on alternative fuels infrastructure (European Commission, 2024b).

Nine priority transport corridors have been identified under this policy: Atlantic, Baltic-Adriatic, Mediterranean, North Sea-Baltic, North Sea-Rhine-Mediterranean (developed in

the following section), Eastern Mediterranean, Rhine-Alps, Rhine-Danube, Scandinavia-Mediterranean. Each has a coordinator who facilitates the implementation of a unified work plan, ensuring that national investments are aligned with overall objectives and eliminate cross-border bottlenecks. The European Commission oversees the overall policy, sets strategic guidelines and ensures that projects are aligned with European objectives, supported by national and regional authorities and infrastructure operators for the implementation of projects (European Commission, 2024b).

Figure 24 North Sea–Rhine–Mediterranean Corridor



Source: Adapted from European Commission (2024a)

North Sea-Rhine-Mediterranean (NSRM) transport corridor

The NSRM corridor spans eight countries (Ireland, the Netherlands, Belgium, Luxembourg, France, Germany, Switzerland and Italy), covering approximately 12,150 kilometres of railways, 5,000 kilometres of roads and 5,030 kilometres of inland waterways. Its configuration is based on three major interconnected axes, serving capital cities, major urban centres and strategic industrial regions. The eastern axis connects Amsterdam to the German Rhine regions, continues through Switzerland and reaches northern Italy to the port of Genoa on the Mediterranean. The western axis starts in Le Havre, crosses Paris, Dijon and Lyon, and then reaches the Mediterranean ports of Marseille and Fos-sur-Mer. The central axis connects Lille, Brussels and Luxembourg before joining the other two routes in Strasbourg and Dijon. These axes form a dense network, complemented by connections to numerous seaports along the Atlantic, the English Channel, the North Sea and the Mediterranean. The NSRM also includes strategic infrastructure such as the Rhine River,

a major waterway in Europe, as well as major projects such as the Gotthard Base Tunnel in Switzerland and the Seine-Scheldt river project linking France and Belgium. (European Commission, 2024a).

Several major projects are underway, including the construction of the Seine–Nord Europe, Saône–Rhône and Saône–Moselle canals in France, as well as a canal bypassing Bruges in Belgium. In terms of road transport, and in order to reduce pressure in urban areas, the main projects concern the extension of the A15 linking Arnhem to the German border and the A16–A13 ring road around Rotterdam in the Netherlands, the completion of the R1 ring road in Antwerp and the Nancy motorway bypass in France (European Commission, 2024a).

The strategic orientation of the NSRM corridor emphasises investment in sustainable modes of transport, particularly rail and river transport, while also incorporating projects related to the digitalisation and decarbonisation of infrastructure. A few achievements that have improved intermodal fluidity are worth mentioning, such as the commissioning in 2007 of the Betuwe railway line, which improved land access to the port of Rotterdam; the opening to traffic in 2016 of the Gotthard Base Tunnel, which strengthens continuity between Northern Europe and Italy; the construction in 2022 of the new IJmuiden sea lock, which guarantees access from the port of Amsterdam to the North Sea, and the development of the Theemsweg railway section to improve access to the port of Rotterdam (European Commission, 2024a).

Synchromodality: the case of the Port of Rotterdam

“Synchromodality involves coordinating the planning of operations across different modal networks in order to minimise delays at interchange points and, as a result, facilitate the

use of multiple modes for the same movement of goods.” (McKinnon, 2019). It aims to improve the efficiency of freight transport by synchronising different modes through accurate, real-time information exchange. In this context, federated data spaces offer a solution by creating decentralised ecosystems that enable secure sharing of critical data (Pulido et al., 2025). However, several challenges limit the effective implementation of synchromodality: data silos due to a lack of trust (Pulido et al., 2025), the absence of common standards, imperfect system interoperability, incomplete near-real-time data transmission, and the heterogeneity of planning tools (Song et al., 2023). These limitations often stem from insufficient data governance and a lack of trust between partner organisations. The success of synchromodality therefore depends on the establishment of clear governance rules and well-defined exchange conditions (Pulido et al., 2025).

In Europe, Rotterdam and Antwerp are the most advanced ports in the deployment of synchromodality. (Brümmerstedt et al., 2017). In particular, the experience of Rotterdam illustrates that this concept is not limited to the simple coexistence of several modes of transport, but is based on the flexibility of their use, made possible by effective information sharing. The Portbase²² community port system (PCS) brings together shipping companies, terminals, river and rail operators, freight forwarders and authorities, standardising messages relating to port calls, slots and documents. Dedicated application services such as hinterland connection planning, river convoy optimisation and connection coordination aim to improve capacity utilisation and, where relevant, support the shift to mass transport modes (Port of Rotterdam, 2019). The objective is not only to exchange information, but also to coordinate operations on a daily basis in order to reduce downtime and increase predictability.

22 See: <https://www.portbase.com/en/about-us/#~:text=Portbase%20is%20the%20executive%20organisation,sustainably%20and%20safely%20as%20possible>

The Port of Rotterdam therefore thrives not only because of its privileged geographical position in Europe, but also because of its ability to align its stakeholders, modes of transport and information flows. The main lessons to be learned for ports in the SLGL region from the example of Rotterdam are as follows:

act as the nerve centre of the multimodal platform, enabling all stakeholders (shipping companies, shippers, customs, trucking companies) to share information and coordinate their actions.

- **Unified port governance with broad stakeholder involvement:** The Port of Rotterdam Authority coordinates long-term strategy and multimodal infrastructure, working closely with shipping companies, terminal operators, rail and river operators, road hauliers and local authorities to align investments and operations.
- **Integrated multimodal operations:** The port integrates land connectivity into its operations by developing rail, river and pipeline links to the hinterland. It applies a synchromodal strategy, offering shippers flexible choices between different modes of transport thanks to digital systems that coordinate barges, trains and trucks in real time. This level of integration requires a high degree of trust and data sharing between stakeholders, but it results in increased efficiency and reliability. It also requires a culture of cooperation, with shipowners, terminal operators and land transport operators working together rather than in isolation. Furthermore, a recent study on the ports of Rotterdam and Antwerp showed that their combined scale and overlapping hinterland networks create synergies; “the whole is greater than the sum of its parts” (Van der Lugt et al., 2025) . This suggests that if ports in the region collaborate rather than compete in a zero-sum game, they too can generate collective gains in market share and value creation.
- **Digital technologies and platforms:** High-performing logistics hubs use technology to increase efficiency. Shared port systems, data portals and automation reduce waiting times and paperwork. In Rotterdam, digital innovations have created a “smart port” offering real-time container tracking and optimised ship berthing. These digital tools

Conclusion

A common vision for 2025: Towards an integrated multimodal transport platform for the SLGL region

The SLGL corridor is at a turning point in its economic history. With a strong industrial heritage and deep binational integration, it has the assets to remain one of the engines of prosperity in North America and around the world. However, the challenges of the 21st century—the digital revolution, increased global competition, environmental requirements—are forcing it to reinvent its growth model. The guiding principle behind this reinvention must be productivity, understood in the broad sense as the ability to create more value in an efficient, sustainable and innovative way.

In this report, we began by reviewing the current context of the SLGL corridor: a global economy driven by intense cross-border trade, but facing geopolitical tensions and structural transportation challenges. In this context, improving productivity is not an option but a necessity to maintain the region's standard of living and economic weight. We then defined productivity, distinguishing between traditional approaches (emphasising the role of capital, labour and exogenous technical progress) and contemporary approaches (emphasising the endogenous role of innovation, human capital, infrastructure, institutions, etc.). These concepts form the theoretical basis on which to build action. Productivity cannot be reduced to a formula, but is a multidimensional phenomenon

that involves optimising all inputs and improving the entire production system. One key idea that emerges is the notion of a hierarchy of levers: the benefits of AI and high technology can only be reaped if there is first a solid foundation of infrastructure and skills: robust and interoperable infrastructure, skilled human capital, a culture of innovation, and finally the deployment of AI tools. The ongoing digital transformation was presented as a change in the function of production, comparable to major historical disruptions. AI, data and automation are redefining the way we produce and offer unprecedented potential for efficiency, but we still need to organise ourselves to exploit it fully.

Our analysis then focused on three interdependent strategic pillars identified as levers for increasing competitiveness: productivity, physical and digital infrastructure, and resilience and sustainability. Productivity involves optimising supply chains, technological integration and the fluidity of trade. The modernisation of physical and digital infrastructure requires sustained investment to prevent service disruptions and adapt to climatic and geopolitical uncertainties. Finally, sustainability relies on better data sharing to avoid inefficiencies, ongoing training of the workforce in new technologies, and the involvement of local and indigenous communities to maximise the positive impacts of supply chains, so that the benefits of supply chains reach as many people as possible.

Several strategic priorities for the attractiveness, competitiveness and productivity of the SLGL corridor can therefore be drawn from the analysis and findings in this report:

1/ Modernise physical and digital infrastructure for an efficient logistics corridor

- **Physical:** invest in port modernisation (capacity, automation), improve and electrify rail corridors (bridges, tunnels and marshalling yards), strengthen the cross-border road network and international bridges to eliminate logistical bottlenecks and enhance resilience. A port is only valuable if it is well connected to its hinterland. The platform must therefore include improvements to road and rail access. This may mean building or optimising motorway interchanges close to terminals to ease heavy goods traffic, or extending rail connections to port terminals.
- **Digital:** Develop digital infrastructure to optimise the flow of goods and services, develop an integrated logistics data platform (customs, rail and maritime flows, warehouse availability). A digital twin of the corridor would enable real-time management by public and private actors.

2/ Accelerate the adoption of digital technology and AI in the private and public sectors

- Promote digital transformation in businesses, including SMEs, through incentives, technology showcases and shared resources.
- Leverage AI in the public sector (traffic management, predictive maintenance, digital services) to increase overall productivity.

3/ Develop human capital and research

- Focus on STEM education, support continuing education and retraining for workers impacted by automation, particularly in industry and logistics.
- Support research applied to regional issues (sustainable mobility, water management, manufacturing AI) through cross-border university and industry partnerships.

4/ Strengthen regional innovation and entrepreneurship

- Develop incubators, accelerators and joint funds to support innovative start-ups and SMEs.
- Attract strategic foreign investment in key sectors (AI, semiconductors, clean mobility) by highlighting the integrated potential of this binational market.

5/ Strengthen governance and cross-border cooperation

- Coordinate policies through enhanced macro-regional governance and a common agenda
- Harmonise regulations and simplify customs and administrative procedures.
- Involve businesses, local authorities and citizens to ensure social acceptability and shared benefits.

6/ Accelerate the ecological transition and decarbonisation of transport and industry

- Support ports in moving towards sustainable models and decarbonise transport (electric vehicles, rail freight, alternative fuels for maritime transport)
- Improve the collection and sharing of data on GHG emissions and the energy efficiency of ships in order to target reduction levers more precisely and assess the real impact of the measures adopted.
- Strengthen binational cooperation with the United States to reduce regulatory fragmentation and facilitate the exchange of best practices.
- Involving local communities and maritime workers in the planning and governance of decarbonisation projects is essential to ensure their acceptance and long-term success.

Strengthening the competitiveness of the SLGL corridor depends above all on optimal coordination among these stakeholders. It is essential to identify the most promising pillars for each stakeholder and to create opportunities for collaboration that transcend institutional and sectoral silos. A coordinated approach at the Canadian level would better align divergent interests and promote strategic cooperation,

maximising synergies between the various partners and supporting an integrated and competitive regional dynamic.

The SLGL corridor has everything it needs to usher in a new phase of productivity-based growth and become a true model of inclusive competitiveness for 21st-century regions. Its economic destiny will not be a repeat of its industrial past, but rather the construction of a smart, integrated corridor where infrastructure, factories and logistics centres operate in synergy and at their full potential. Achieving this goal will require vision, coordination and sustained investment, but the benefits in terms of shared and sustainable prosperity amply justify these efforts.

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