# A Digital Twin Ecosystem for the Great Lakes–St. Lawrence River Maritime Corridor

Report of the Intelligent Maritime Corridors International Council (IMC IC) Digital Twin Strategic Table

Image generated using ChatGPT (OpenAI, 2025).

Summary Report

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CI CMI
Conseil International pour les Corridors Maritimes Intelligents

IMC IC
Intelligent Maritime Corridors International Council

# Table of Contents

## Introduction

The current global trade and geopolitical context, foreseeably unstable and continuously changing, provides opportunities requiring a consolidated strategic and tactical approach to position Canada as an international leader in intelligent maritime corridors (IMCs). The Great Lakes–St. Lawrence River (GL–SL) corridor is a critical economic artery in the North American supply chain. Its economic power stands as one of the largest in the world. But like any maritime corridor, it faces enormous pressures in terms of capacity, emissions reduction, sustainability and socio-economic impacts. Growing digitalization and the rise of artificial intelligence only increase the pressure to accelerate digital transformation. The major players in international ports and maritime corridors are turning to the development of technological solutions to take full advantage of this new transformation and embrace IMCs. Given the greater capacity and performance expectations in the current geopolitical context, the GL–SL corridor has no choice but to rely on innovation and this transformation. Maritime corridors that leverage these technologies and address these pressures will be more efficient and resilient, becoming the leaders of tomorrow in an increasingly competitive world.

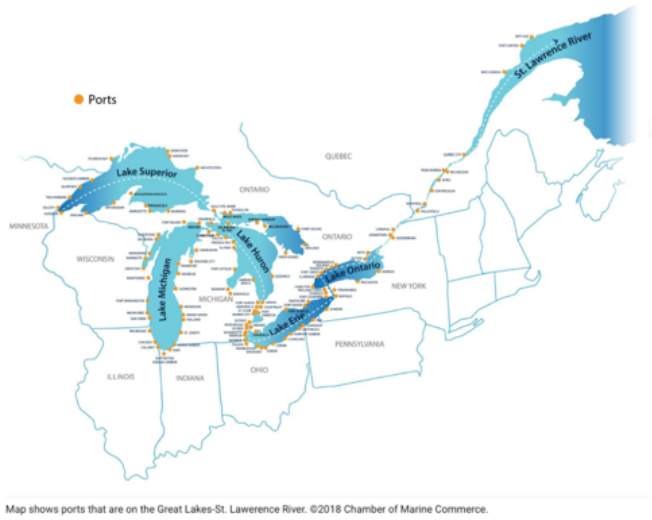
The Digital Twin Strategic Table, operating under the authority of the Intelligent Maritime Corridors International Council (IMC IC), brings together prominent experts from various fields with in-depth, high-level knowledge of marine transportation, research, innovation and data science in the public, private, academic and/or not-for-profit sector.

This is an opportunity for the GL–SL corridor to take charge of its destiny and position itself as an international showcase and living lab for a sustainable and intelligent maritime corridor.

## The GL–SL Corridor: The Heart of the North American Economy

According to *Economic Impacts of Maritime Shipping in the Great Lakes–St. Lawrence Region* (Martin Associates, 2023), if the GL–SL region were a country, its gross domestic product would be the third-largest in the world, behind the U.S. and China. The GL–SL corridor is at the heart of the Canadian and North American economy, linking the interior of the continent to international markets via the Atlantic Ocean.

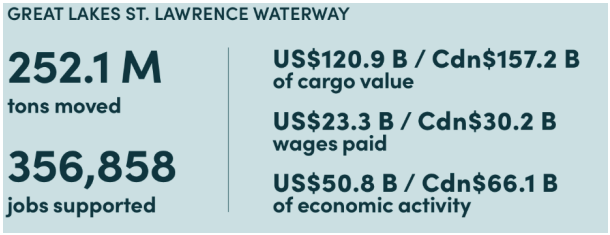
*Figure 1: Ports on the Great Lakes and St. Lawrence River (Chamber of Marine Commerce, 2018)*




The report confirms the scale of these economic impacts:

- More than **252 million tonnes** of cargo moved through the GL–SL region in 2022.
- Close to **357,000 jobs** supported, including **81,000 direct jobs**.
- Over **$66 billion dollars of economic activity**.

*Figure 2: Economic Impact of the GL–SL corridor (Martin Associates, 2023)*




## The Maritime Transportation World in Transformation

The shipping sector, both local and international, is facing a considerable industrial revolution. It is under constant pressure from forces not necessarily under its control, including:

**Climate change:** Increasing climate variability leading to more frequent extremes, including greater fluctuations in water levels and ice cover, droughts, floods and violent storms, means a higher risk for ships, operators and other players. What were once established routes and waterways may not persist into the future.

**Environmental and social requirements:** Pressures to reduce the transportation sector's environmental and social impacts continue to grow. Efforts to reduce emissions, the energy transition and the United Nations Sustainable Development Goals must be factored into any strategy.

**The fragility of supply chains:** The COVID-19 pandemic, geopolitical tensions, market disruptions and labour shortages have all shown how vulnerable transportation systems are to external shocks.

**The digital revolution (digitalization):** Artificial intelligence, big data analytics, decision automation and digital twins are rapidly transforming operational practices in maritime shipping, including the availability of workers with the skills needed for the future.

Maritime corridors that take advantage of state-of-the-art technologies and address these pressures will be more efficient and resilient, and better poised to lead in an increasingly competitive environment.

## Digital Twins: A Strategic Lever

**Digital Twin applied to the concept of an intelligent maritime corridor:** A digital twin is a virtual representation of a physical object, process, system or person. It is an accurate, real-time digital replica of a real-world asset. The concept of the digital twin is used in various fields, such as industry, engineering, the Internet of Things (IoT) and information technology. A digital twin is created using data from sensors, computer models and other sources to faithfully reproduce the state and behaviour of a physical object in the virtual world. The idea is to enable designers, engineers and managers to gain a better understanding of how a real system works so they can then predict behaviours, diagnose potential problems and optimize performance. In an IMC, digital twins can be used to carry out simulations, tests and analyses without impacting the real system, which can cut costs, reduce uncertainties and improve risk management.

According to the IMC IC Digital Twin Strategic Table, the digital twin of an intelligent maritime corridor must entail an **ecosystem of public- and private-sector digital twin projects**, whose core architecture and analytical technologies are designed to benefit all stakeholders. This intelligent digital twin ecosystem will allow the corridor to progressively build upon the knowledge acquired by each of the stakeholders and, over time, become a more interconnected and interoperable network of virtual models representing ships, navigation, ports, locks, waterways, logistics systems, and natural and social environments. The result will be more reliable information and predictive analyses to support evidence-based decision-making, optimize operations, protect ecosystems, strengthen sustainability and resilience to climate change, and enhance international competitiveness. It is however critical to recognize and consider that, in the maritime context, a digital twin is never perfect and never static. It requires constant updating to reflect the frequent changes in bathymetry and hydrodynamics as well as new data.

*« A digital twin of an IMC is a representation of a dynamic and coherent ecosystem of sectoral digital twins, whose combined actions and analyses contribute to strengthening the supply chain and increasing the economic performance of an entire maritime system. »*

Considering the scale of the GL–SL maritime corridor, the transformation to an IMC will need to be supported by a digital environment and a multitude of digital twins including updated versions as they become available. This will take a unified and collaborative vision leading to an ecosystem that fosters innovation and the development of interconnected digital twins. In addition to optimizing local operations, the resulting IMC has the potential to influence international interoperability and sustainability standards.

The structure of the ecosystem is made up of functional layers with a technical, operational, situational, environmental or infrastructure focus. This modular approach lets users select the layers in line with their specific needs and simulate their interactions. Each layer, by design, will allow the free exchange of information with other layers, leveraging the established standards and interoperability protocols at the very foundation of the system.

This interoperability acts as a central digital hub, ensuring the smooth, secure and relevant flow of information within the ecosystem.

In an ecosystem with interconnected digital twins, each of the players (shipping, port operations, infrastructure, environment, energy, logistics, etc.) maintains their own digital representation while being part of an interoperable whole.

Governance rules, standards and other elements related to functionality and interoperability will also need to be incorporated into the ecosystem and protected by a cybersecurity layer.

However, there is no national or binational framework to integrate these efforts in a coherent digital twin ecosystem spanning the entire GL–SL corridor. Governance remains fragmented and data interoperability limited.

## Main Findings of the Strategic Table

One of the first findings from the Strategic Table's discussions concerns the absence of a common and clear Canadian vision for the development of the intelligent maritime corridor and digital twins. Although several innovation and digitalization initiatives are underway, they remain isolated and poorly interconnected. In this context, the establishment of a single digital twin for the entire IMC is a difficult goal to achieve, particularly due to the accelerated pace of change brought about by the data environment and the rise of artificial intelligence.

As the value and usefulness of digital twins increase, the interoperability challenges will increase with no current alignment or standards to guide initiatives. During the discussions, it became apparent and essential to rally around international standards to ensure this interoperability. Without a clear vision or governance, the risks of innovations taking place in silos increase and limit the full digital potential of the corridor. It will be necessary to create an environment that balances standards and open data in a reference

framework that will facilitate the advancement and development of the IMCs. This could consequently require creating new standards to move forward more quickly.

Ensuring quality control and managing data variability are equally as critical. Similar data from multiple sources frequently differs in terms of quality, value or resolution. The value of the data may also vary depending on how it is used. For example, the data required to ensure accurate vessel navigation may not be particularly important to anyone else. Data sovereignty and long-term availability are other key factors. It will be necessary to consider how to preserve and protect this data for its sustainability and future accessibility. These levels of accuracy, resolution and use will have to be part of the data governance framework.

The uneven adoption of international standards is another serious roadblock. Although standards exist, their application is often partial, fragmented or adapted to local contexts. Standards excel at enforcing compliance but are limited in their flexibility. A balance must therefore be struck between compliance with internationally recognized standards and the flexibility required to accelerate corridor development.

It is also important to consider Canadian data sovereignty and independence. Data available today may not be available tomorrow or may need further protection. This is a vital consideration from a governance perspective. Many organizations are also reluctant to share data or change processes for fear of losing their competitive advantage.

## Vision and Ambition

Establishing a clear vision is paramount to creating a clear and aligned direction for the maritime corridor. From the outset, the Strategic Table's members expressed the need to fully understand what was being asked and to ensure that they were working toward a common goal. After a series of exercises and discussions, the following vision statement was finalized by the members and the IMC IC Board of Directors.

**The vision:**

> *" Propelled by the IMC-IC and its partners, the binational Great Lakes–St. Lawrence maritime corridor becomes an intelligent maritime corridor, supported by a concerted digital twin ecosystem, integrated into an evolving multimodal environment, thus contributing to the vitality of the North American economy and ranking itself among the world's leading authorities in this field."*

This shared vision provides a framework for discussions and recommendations, aligning stakeholders with diverse agendas. It embodies an ambition to work together to transform the GL–SL maritime corridor into an integrated, technologically flexible digital corridor with a strong focus on competitiveness. Above all, it unites stakeholders around a common language.

**The mission:**

*The IMC IC and its partners are committed to influencing and guiding the creation of an integrated digital twin ecosystem in support of developing an intelligent maritime corridor for the Great Lakes and the St. Lawrence River.*

This mission is based on three levers of action:

- **Develop in-depth strategic intelligence** of the current ecosystem, by mapping existing and upcoming initiatives, analyzing the state of available data and understanding the uses and needs of current users.
- **Identify critical gaps and influence** the most promising strategic opportunities for maritime innovation.
- **Identify and proactively propose** specific projects to relevant institutions, governments, non-profits and academic organizations to create an integrated dynamic ecosystem of digital twins with one or more operational testbeds in the GL–SL corridor.

This would make the corridor a living lab, where data, technology and governance come together to advance a sustainable maritime future.

## Strategic Pillars

**A multilevel governance:** There is neither a clear vision nor an articulated and coordinated governance in place for the development of an intelligent maritime corridor in Canada. There is also a clear lack of a structured plan and coordination between the various stakeholders and jurisdictions for the digitalization of the corridor. Innovation occurs in silos, which amplifies the existing gaps and leads to potential unnecessary duplication. The public–private data divide continues to grow as the volume of data increases. The corridor's digital environment is a jumble of non-hierarchical systems that prevents it from reaching its full potential.

The governance framework must clarify the roles and responsibilities of each of the stakeholders, establish reference frameworks for innovation and data governance, and set out decision-making, funding and regulatory mechanisms. Guidelines and policies will also need to be defined or redefined.

It is recommended to prioritize the development of a thorough, neutral and inclusive governance structure or model under the leadership of a unifying entity that incorporates the identified principles. In the absence of an existing entity, the IMC IC should act as an interim facilitator and willing enabler for these groups to identify challenges and opportunities and to reach a common understanding. A neutral space will need to be established where guardians and users can work together around a common vision to create this governance framework tailored to the needs of an intelligent maritime corridor.

**A shared space for interoperable data:** The availability of data and its ability to support a digital twin ecosystem environment have been fundamentally accepted. The power that

data represents must be reflected in all aspects of any work on the vision, frameworks, collaborations, agreements and other elements. We are on the verge of influencing the data economy, if we aren't already there. Data will be the wind in the digital sails of the future. Its findability, accessibility, interoperability and reusability (FAIR) will become critical issues in the new digital environment. We will have to trust the data, trust the authorized and certified stewards who manage and share it, and find ways to make it accessible without compromising its value or quality.

*Data will be the key resource for advancement and innovation. Its quality, availability and accessibility will become the critical issues.*

The development of a digital twin ecosystem requires the creation of a FAIR-compliant and shared data space while ensuring security and sovereignty and protecting the interests of its stakeholders. Although the use of regulations and standards obviously facilitates exchange, communication and the potential for shareability, stakeholders do not always apply them consistently. The transition from one standard to another often requires a significant investment. And standards can sometimes hinder rapid advancement.

We must therefore balance compliance with existing standards against the potential to find quick solutions. Given the accelerated pace of technological and artificial intelligence developments, it is also necessary to remain agile and build a flexible, scalable environment.

The Strategic Table's members have repeatedly emphasized the importance of creating a climate of trust that ensures neutrality, transparency and verifiable data quality and provenance. Companies will only share their sensitive data if a neutral and secure framework is in place. Good governance must strike a balance between full or partial public access to data and the protection of commercial data. The goal is not necessarily to have all the data – a subset may suffice – but ensuring known quality and adherence to the FAIR principles is paramount. Effective data governance promotes the smooth flow of information, fosters trust and engagement, and paves the way for innovation. Without a governance framework, stakeholders remain siloed in their own systems, hindering corridor integration and limiting the potential of interconnected digital twins.

**Innovation and demonstration:** While data quality is important, the culture of innovation must also be considered. Organizations do not all have the same level of maturity when it comes to adopting new technologies and integrating artificial intelligence. For many, decision-making processes are still based on analogue or manual methodologies. They will need to adapt and automate these processes and use simulation and forecasting tools that allow dynamic adjustments in real time. This will require specific attention to user interfaces, which will need to be user-friendly and tailored to the operational realities of workers.

**Environment and sustainability:** Environmental and societal issues must be considered as a priority during the transformation of the corridor. It is impossible to think of the operation of the corridor without considering the impacts and influence that these two areas can have on its operability, and vice versa. It will be important to identify and consult coastal and Indigenous communities to fully understand their needs and concerns regarding the impacts of the corridor. Digital twins can help simulate the bidirectional impacts of elements such as water levels, tides, erosion, climate, biodiversity, sensitive areas and, flood zones, to name a few.

Commercial navigation needs to work together with riparian and indigenous communities all while respecting and protecting biodiversity and the environment.

## A Roadmap to 2040

The discussions shed light on several important elements relevant to the successful development of an ecosystem of interconnected digital twins. **Federal leadership and a strong, multi-layered governance plan** that would ensure the participation of different governments and stakeholders are essential. It will take a solid, aligned and transparent foundation to build trust with a clear voice and a clear path.

Developing a **robust, FAIR-compliant data framework** for the digital ecosystem will be crucial. A comprehensive data governance system must be created to support the intelligent governance of the maritime corridor. This system must provide a secure, transparent and trustworthy data space, where data can be used with confidence and interoperability is maximized.

**Sustainability considerations will be key.** The actions we take today will have long-term impacts on the economy, the environment and society. In developing the roadmap and ecosystem, we have aligned our approach with the United Nations' sustainability and decarbonization strategies.

The importance of **collaboration and inclusivity** cannot be overstated. A single-level or sector-specific approach will not suffice. Governance and strategies for the IMC and its ecosystem will need to include governments at all levels, including municipal and Indigenous communities along the corridor, as well as regulatory bodies, data owners and other system users.

Finally, we need to **determine how to fund** these efforts. Transforming our waterway and the GL–SL hydrospatial domain into a virtual ecosystem will not only require significant investments but must also become an integral part of long-term federal and provincial marine transportation strategies. This will require commitments from governments, industry, not-for-profit organizations, academia and, potentially, private philanthropists. An intelligent maritime corridor supported by an interconnected ecosystem of digital twins is essential for Canada's blue economy and sustainable growth.

In documenting the required actions, we have realized that this is no easy task. We are putting forward a vision that looks to 2040, but action must begin today. With a project of

this magnitude, many stakeholders will need to be consulted. A comprehensive roadmap will have to be developed to address their needs.

**Phase 1 (2026-2028)** Vision, Governance and Actions

**Phase 2 (2028-2031)** Innovation and Growth

**Phase 3 (2031-2040)** Momentum and Recognition

The Strategic Table has suggested some short-term actions as a starting point. The phased approach highlights some of the key activities and actions over time.

## An Essential Financial Collaboration

It is often difficult for organizations to plan beyond a 15-year horizon. Achieving this kind of transformation will require a significant amount of collaboration. The corridor spans eight states, two provinces and a multitude of municipal and Indigenous communities. There will be contact with two federal governments and the corresponding departments, in addition to European and Asian countries and industries that take an interest in the initiative. Structured collaboration with a strong communications network and clear messages will be essential.

Government-level decision-makers will dictate policies, laws and financial commitments. Regulators will ensure the system works efficiently.

We must also consider the massive investments that will have to be made. Government funding for these initiatives will not be guaranteed. While some programs already exist, there are reports of future spending cuts while realigning to build a new and strong economy and investing in Canada's security and sovereignty. Strategies must support governments' strategic plans and demonstrate ROI. A sustainable governance and funding model, including decision-making mechanisms, must be defined.

## Strategic Conclusion

The full report summarizes some of the key actions that will need to be taken. It aims to offer a broader view of the transformation that must take place if we are to fully realize the corridor's potential. The constraints and pressures imposed by the economy, the environment and the political climate will persist, but they can also serve as unprecedented opportunities for learning and growth to make the GL–SL maritime corridor and the hydrospatial domain an international example of competitiveness, sustainability and collaboration.

1. *Establish Canadian leadership with a multi-level governance framework.*
2. *Create a secure, accessible and interoperable data space.*
3. *Create and promote a collaborative environment.*
4. *Integrate decarbonization and sustainable development objectives.*
5. *Catalyze flagship pilot projects.*
6. *Establish a funding model to ensure sustainability.*

It is therefore recommended to establish a funding strategy framework with an inventory of financial, societal and environmental benefits that can ensure a consistent approach with clear, compelling messages that can be used to approach decision-makers and investors.

**To conclude:** The Strategic Table's discussions clearly pointed to a lack of leadership and the absence of a well-defined vision for developing an IMC, including a lack of action in terms of data standardization and access. Federal, provincial, territorial and state governments in Canada and the U.S. will need to be convinced of the importance of establishing a vision and a multi-level governance framework to transform this corridor and maximize its capacity, competitiveness, resilience and sustainability.

The Table proposes potential solutions as well as six recommendations and priority actions to guide the IMC IC in accelerating the transformation of the GL–SL corridor. It contains a step-by-step roadmap outlining a set of ambitious yet realistic actions.

To achieve this, it will be essential to embrace a coherent and collaborative approach that aligns all levels of government, regulatory authorities, researchers, innovators, users and others. Multi-level governance structures will be key to building this cooperative, innovation-driven environment.

The result will allow the various players to optimize their operations and develop innovative, interoperable technological solutions, which will in turn unlock new possibilities

# Document Information

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The information contained in this report reflects a point-in-time analysis based on information available at the time of preparation and is subject to change.

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