Canada-European trade corridor: review of research and development needs and opportunities

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Canada-European Trade Corridor Review of Research and Development Needs and Opportunities

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Executive Summary

Canada is a resource and innovation rich nation with close connections to Europe.

In 2016, the Government of Canada signed the landmark Canada-European Union Comprehensive Economic and Trade Agreement, which provides Canadian organizations with unprecedented access to the European market. While trade between Canada and the European Union has existed in the past, the trade agreement is expected to usher in increasing volumes of trade activities and economic opportunities for Canadian businesses in the coming years.

The objective of this project is to examine the movement of goods between Canada and Europe, to better understand key players, the transportation equation, challenges and bottlenecks, and opportunities for research and development to improve safety, security, efficiency and environmental sustainability.

A review of available literature was completed in order to better understand the movement of goods between Canada and the EU. The literature review examined the following elements:

- Canadian industries that currently export to Europe, along with an analysis of industries who will either begin to export to Europe or who will increase exports to Europe due to the ratification of CETA;
- The end-to-end flow of goods, the role of transportation in trade and a general overview of the sector;
- The key players involved in end-to-end movement of goods; and
- Challenges for the sector

Select stakeholders from the end-to-end movement of goods along the Canada-European trade corridor were also consulted relating to their experience and challenges within the sector.

The following key research opportunity areas were identified to have the potential to generate society level impacts within the transportation, logistics and distribution sector:

1. Big data and data analytics;
2. Monitoring, modelling and predictive analytics;
3. Artificial intelligence;
4. Blockchain;
5. Cyber and physical security;
6. Physical internet & cloud computing;
7. Intelligent transportation systems;
8. Collaborative logistics and approaches;
9. Standardization, regulations, rules and policies; and
10. Sustainable supply chain.

Glossary and Definitions

1G	First generation
4G	Fourth generation
5G	Fifth generation
1PL	First party logistics
2PL	Second party logistics
3PL	Third party logistics
4PL	Fourth party logistics
AI	Artificial intelligence
AIS	Automatic identification systems
CETA	Canada-European Union comprehensive economic and trade agreement
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GIS	Geographical information systems
GPS	Global positioning systems
ICT	Information and communication technologies
ITS	Intelligent transportation systems
NRC	National Research Council of Canada
POM	Port of Montreal
POH	Port of Halifax
R&D	Research and development
RFID	Radio-frequency identification
SITC	Standard international trade classification
SME	Small and medium sized enterprise
TCS	Canadian Trade Commissioner Service
UAV	Unmanned aerial vehicles
UK	United Kingdom
VRP	Vehicle routing problem

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1 Background

Canada, with a gross domestic product (GDP) of $2.145 trillion dollars (2017, [1]) is a resource and innovation rich nation. Figure 1 illustrates the relative comparison between key sectors within the Canadian economy based on economic data from 2017.

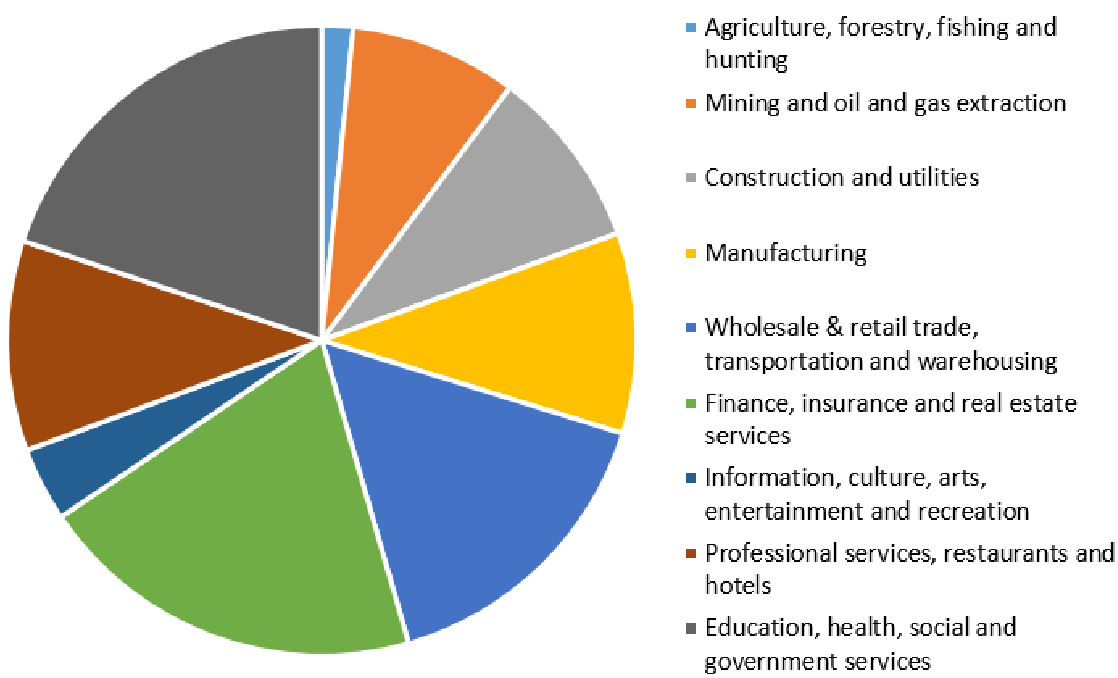

Figure 1: GDP Overview by Key Sector [1]

From 2013 to 2017, a significant percentage of annual GDP (62% to 65.5%) was a result of international trade of goods and services.

International trade facilitates globalization, referring to the concept whereby key activities that bring goods and services from inception through to end use are no longer confined to a single organization or a single location [2].

According to the Office of the Chief Economist of the Canadian Trade Commissioner Service (TCS) [2],

> *Globalization enables organizations within each value chain (or supply chain) to specialize in what it does best, which leads to greater efficiency, increased productivity and lower consumer prices for higher-quality goods and services. At the same time, this trade environment stimulates the intense global competition that encourages innovation.*
>
> *In general, Canada has been reasonably successful at adapting. Our excellent research and development (R&D) environment and highly skilled workforce, together with our long experience as a trading nation, have underpinned this success. However, Canada now has to meet the*

challenge of supporting a technologically advanced and diversified economy. Canadian businesses can do this by creating Global Supply Chain or Global Value Chain for their industry sector, by participating in existing chains, by merging with larger firms or by acquiring other companies.

Three factors have played a key role in globalization [2]:

- Trade agreements – treaties between countries that reduce trade barriers and lower tariffs have created opportunities in new markets for businesses and industries.
- Transportation – efficient movement of goods and services and the reduction of cost has enabled companies to move products to market at an unprecedented rate, as well as improve their overall efficiency by moving portions of their production to the most competitive locations.
- Information and communication technologies (ICT) – recent developments in information and technology has given businesses more tools to operate effectively in foreign markets.

On October 30, 2016, the Government of Canada signed the landmark Canada-European Union Comprehensive Economic and Trade Agreement (CETA), with the European Union (EU), which has since entered into effect (September 21, 2017) [3].

CETA is significant, since the agreement provides Canadian organizations with unprecedented access to the European market. The EU is one of the largest economies in the world, with twenty-seven member countries (2021) as shown in Figure 2 and approximately 446 million people [4].

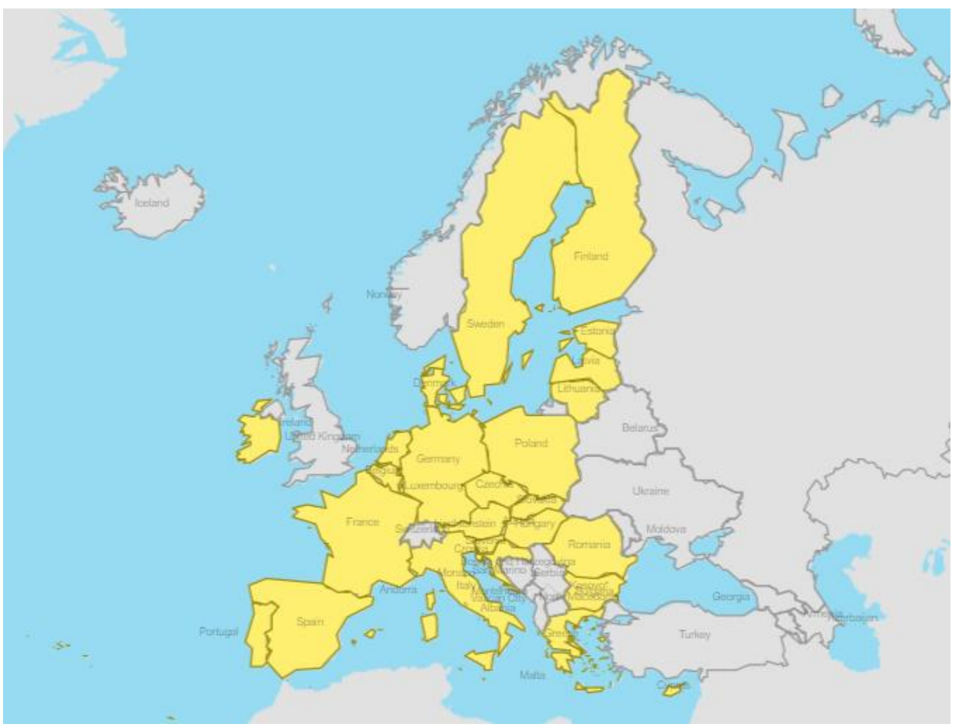

Figure 2: EU Member Countries as of 2021 [5]

Prior to CETA, only 25% of Canadian goods were duty-free in the EU, once CETA is fully enacted (2024), tariffs on 99% of Canadian goods will be removed in the EU.

TCS provides support for Canadian organizations looking to do business internationally. The following are excerpts from TCS' guide for Canadian business for the EU market [6], which provides some context for doing business with the EU:

> *The EU is a highly diverse market and imports primary products, raw materials and energy, along with capital equipment, chemicals and consumer goods*.
>
> *The EU can be a challenging place for businesses… EU regulations and directives can be complex and, in some cases, can create market-access difficulties for Canadian exporters. Furthermore, the EU single market is not complete—national and sub-national rules continue to co-exist with EU-level laws in many areas (e.g. commercial law, labour regulations, and transportation); uneven and delayed implementation of EU rules by member states fragments the internal market. Finally, and perhaps more importantly, the EU remains a union of 27 sovereign countries, with 24 official languages and many diverse cultures, economic profiles and business opportunities. To be successful in the EU, it is important to understand these differences.*

While trade between Canada and the EU has existed in the past, CETA is expected to usher in increasing volumes of trade activities and economic opportunities for Canadian businesses in the coming years.

The objective of this project is to examine the movement of goods between Canada and Europe, to better understand key players, the transportation equation, challenges and bottlenecks, and opportunities for research and development (R&D) to improve safety, security, efficiency and environmental sustainability.

2 Literature Review Summary

A review of available literature was completed in order to better understand the movement of goods between Canada and the EU. The literature review examined the following elements:

- Canadian industries that currently export to Europe, along with an analysis of industries who will either begin to export to Europe or who will increase exports to Europe due to the ratification of CETA;
- The end-to-end flow of goods, the role of transportation in trade and a general overview of the sector;
- The key players involved in end-to-end movement of goods; and
- Challenges for the sector

2.1 Overview of Canadian Industries that Export to Europe

Data from the European Commission indicated that the most traded goods between Canada and the EU in 2020, by Standard International Trade Classification (SITC) include, iron ore and concentrates, oil seeds and oleaginous fruits, aircraft and associated equipment, and engines and motors (non-electric) [7].

According to Global Affairs Canada, the United Kingdom[1] (UK) is Canada's largest merchandize trading partner within Europe in 2020 [8]. Since UK's departure from the EU, Germany has become the largest EU export destination for Canadian goods, followed by Belgium, the Netherlands, France, Italy and Spain (2020) [7].

TCS indicated that Canadian export of services to the EU is also substantial. Top service categories exported to Europe in 2013 include, management services ($1.8 billion), R&D (almost $1.3 billion), financial services ($1.3 billion), computer and information services ($1.2 billion), charges for the use of intellectual property ($598 million) and architectural, engineering and other technical services ($675 million) [6].

Global Affairs Canada identified twelve key sectors that will benefit from opportunities created by CETA [3] due to the elimination of tariffs, access to EU government procurement opportunities, regulatory cooperation, conformity agreements, and improved labour provisions. Canadian businesses within the following industry sectors will likely begin to export to Europe or will increase exports to Europe in the coming years,

1. Aerospace
2. Agriculture and agri-food
3. Automotive
4. Clean technologies
5. Fish and seafood
6. Forestry and wood products

[1] The UK withdrew from the EU on January 31, 2020.

7. ICT
8. Infrastructure
9. Medical devices
10. Metals, mining and minerals
11. Oil and Gas
12. Pharmaceuticals

2.2 Overview of the End-to-End Flow of Goods

Globalization, international trade and the close integration of the world's economy has increased the complexity of the movement of goods.

The term "end-to-end flow of goods" encompasses the movement of goods from inception through to the market place, including the movements of parts and components. It is best described by the concept of a supply chain, as illustrated by Figure 3.

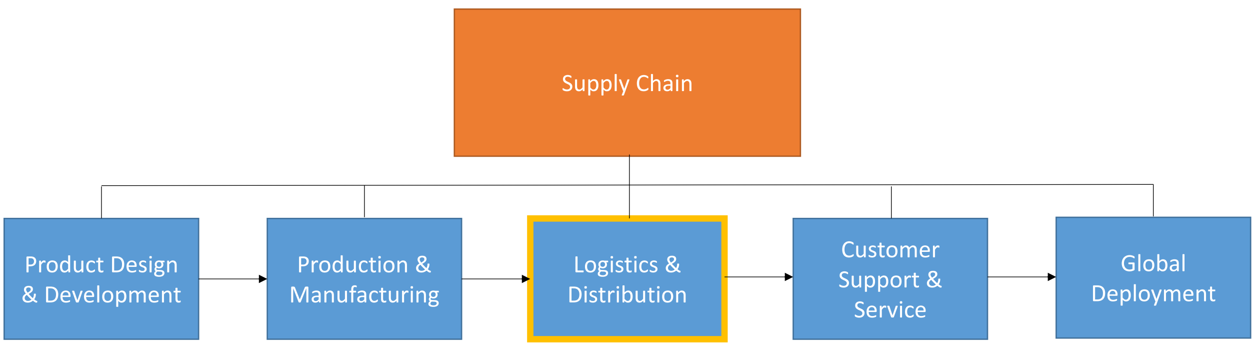

Figure 3: Global Supply Chain Management [2]

Globalization enables activities within each step of the supply chain to take place at a location that is able to provide the best competitive edge. As a result, the movement of a product or component might go through multiple supply chain cycles, and might become part of the supply chain cycle of another product.

As a result, competition is becoming increasingly more global in scale, and a key to successful business practice is improving efficiencies across the entire supply chain.

A 2011 study by Industry Canada on "Global Business Strategy and Innovation" found that larger firms tend to operate with a supply chain that is more global compared to small and medium sized enterprises (SME). An example is shown in Figure 4 of the manufacturing sector in 2011, where strategic sourcing is comparatively smaller for smaller enterprises. It is also interesting to note that in 2011, before CETA, business activities in the manufacturing sector with the EU is smaller compared to business with the United States or Asia. This is the case regardless of the size of the firm [9]

Figure 4: Location of Strategic Sourcing by Business Size, 2011 [9]

Larger firms, especially those in sectors such as vehicle manufacturing, tend to make supply chain decisions on an international scale, as those organizations often have subsidiaries and suppliers in multiple countries. Other sectors, such as those related to the consumer products supply chain, generally make supply chain decisions in Canada based on the domestic market [9].

Industries such as pharmaceuticals and manufacturing have integrated supply chain with the EU, importing finished product, as often is the case for pharmaceutical products, or importing components (such as for aerospace and industrial electronics) for final assembly in Canada (Figure 5). In sectors such as retail, food and mining, the supply chain is less integrated with the EU [8].

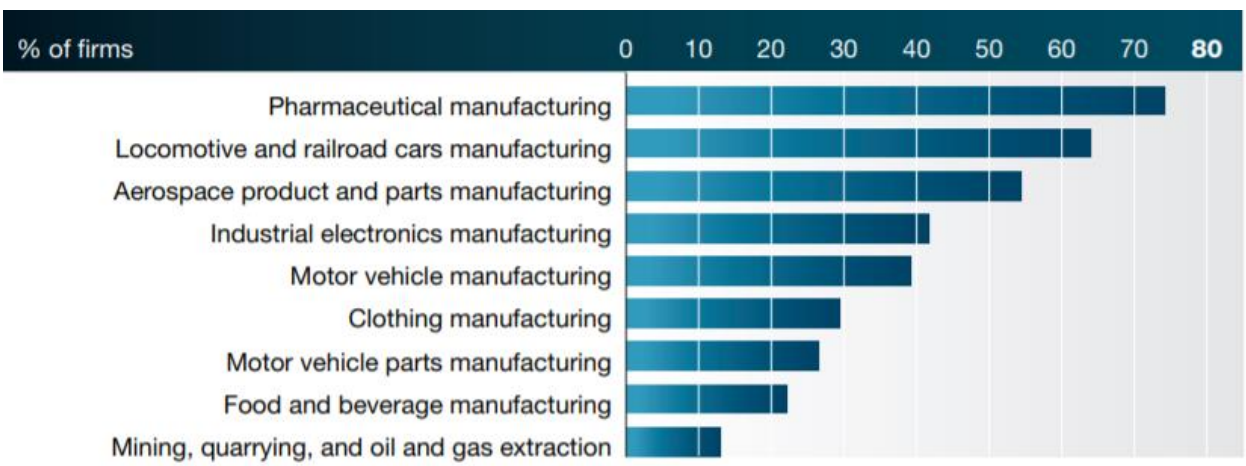

Figure 5: Canadian Enterprises that have Main Suppliers in Europe by Industry, 2011 [9]

2.3 The Role of Transportation in Trade

The ultimate goal of any business is to ensure that they are able to efficiently and cost effectively produce components, products and services, and bring them to market. Transportation plays an integral role in four of the five key steps within global supply chains, including product design and development, production and manufacturing, logistics and distribution and global deployment. It is also an enabling factor for globalization and international trade, and in the context of the EU, a key element to help Canadian businesses benefit from the economic opportunities from CETA.

In today's economy, the role of transportation is no longer limited to freight carriers. In fact, transportation is deeply integrated within the "logistics and distribution" space as illustrated by Figure 6.

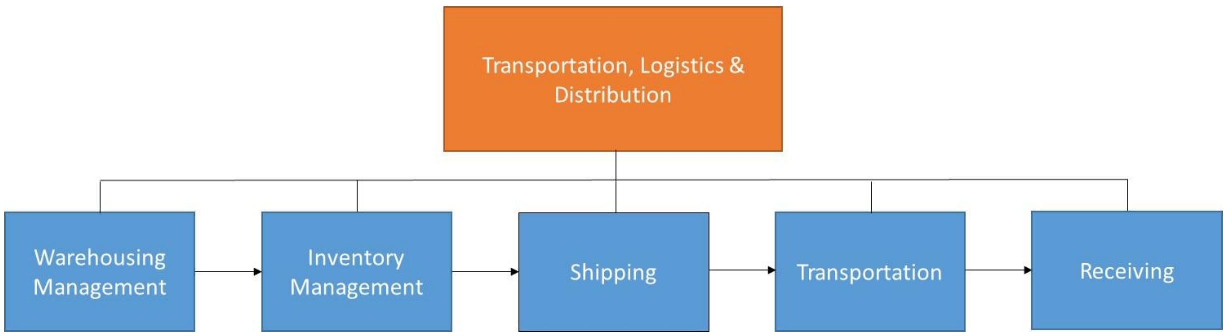

Figure 6: Transportation, Logistics and Distribution [10]

2.4 General Overview of the Sector

There are four primary transportation methods for the movement of goods between Canada and Europe:

- road
- rail
- marine
- air

The method(s) of transportation chosen depends largely on cost, duration and availability of the mode of transport. Often a combination of different modes are used. For example, with an extensive network of roads in both Canada and the EU, road transportation is commonly used to transport freight during its "first" and "last" mile. Rail is the method used for long distance shipping within Canada due to its comparatively lower cost. Marine transportation is the only economical means to transport large volume commodities across oceans, but require long transit times. Within North America, many marine ports have extensive rail connections. While air transportation is the most expensive option, it is the fastest and practical for certain value commodities.

Data from Statistics Canada on the transportation and warehouse industry within Canada in terms of GDP, number of employees and extensiveness of locations are shown in Table 1, Table 2 and Table 3, respectively.

Transportation Mode	2013	2014	2015	2016	2017
Trucking	19.35	20.52	21.03	21.55	22.45
Rail	6.64	7.22	7.47	7.25	7.69
Marine	1.39	1.39	1.48	1.50	1.58
Air	6.25	7.27	8.05	8.86	9.85
Pipeline	4.91	5.33	5.54	5.81	6.00
Support activities for transportation	12.12	13.03	13.48	14.21	14.85
Postal service	3.19	3.11	2.91	2.81	2.94
Couriers and messengers	3.67	3.54	3.52	3.44	3.44
Warehousing and storage	2.37	2.43	2.41	2.59	2.67

Table 1: Transportation and Warehousing Sector by GDP, 2013 to 2017 (x $1,000,000) [10]

Transportation Mode	2013	2014	2015	2016	2017
Trucking	189,381	192,924	195,965	195,841	200,821
Rail	37,420	40,821	42,775	44,064	45,250
Marine	x[2]	x	x	x	x
Air	68,327	69,950	70,229	71,481	73,372
Pipeline	x	x	x	x	x
Support activities for transportation	103,242	107,946	111,035	113,308	113,890
Postal service	x	x	x	x	x
Couriers and messengers	48,281	46,872	46,873	45,738	47,465
Warehousing and storage	43,985	44,853	44,389	47,813	49,221

Table 2: Transportation and Warehousing Sector, by Number of Employee, 2013 to 2017 [10]

Transportation Mode	2014	2015	2016	2017
Trucking	41,062	42,629	45,798	46,120
Rail	198	202	196	288
Marine	332	315	316	306
Air	1,123	1,090	1,120	1,121
Pipeline	195	197	211	183
Support activities for transportation	8,290	8,380	8,677	8,824
Postal service	332	296	277	265
Couriers and messengers	3,039	3,065	3,162	3,185
Warehousing and storage	2,785	2,767	2,769	2,817

Table 3: Transportation and Warehousing Sector, by Number of Business Locations, 2014 to 2017 [10]

It is clear from the size of the sector (GDP and number of employees) that it is very economically significant for Canada. In addition, judging from the number of locations existing within each transportation mode, it is clear that the industry as a whole and supporting infrastructure within Canada is extensive and likely able to provide sufficient capacity to support increased exports to the EU.

[2] Not available due to confidentiality requirements under the *Statistics Act*. [10]

2.5 Key Players in the End-to-End Movement of Goods

The end-to-end flow of goods often involves numerous companies and organizations. They can generally be categorized from first party logistic organizations to fourth party logistic organizations, as illustrated by the pyramid configuration in Figure 7.

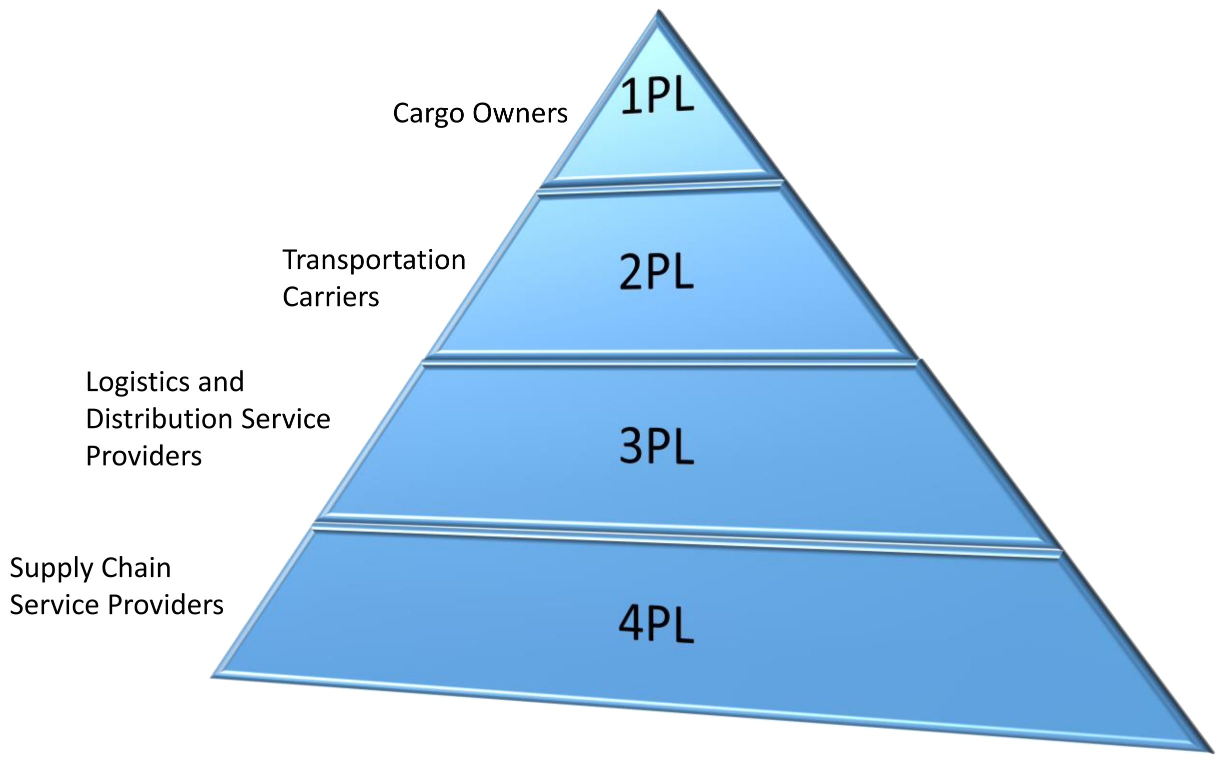

Figure 7: Key Players in the End-to-end Movement of Goods [10]

First party logistic (1PL) organizations generally refer to businesses which owns its transportation fleet. PepsiCo is a good example of a 1PL organization with its private fleet of 11,225 tractors and 3,605 trucks [10].

Second party logistic (2PL) organizations are transportation carriers, such as UPS and FedEx. Cargo owners, third party logistic organizations and fourth party logistic organizations, outsource the transport of goods and commodities to 2PL organizations. In 2017, the largest 2PL in Canada was Canadian National Railway with approximately $US 9 billion in revenue [10].

Third party logistic (3PL) organizations are often referred to as freight forwarders, though they also provide a range of logistical services as shown in Figure 6, including warehousing management, inventory management, shipping, transportation logistics planning and receiving [10]. TCS recommended the use of 3PL organizations for SMEs looking to export goods and services to the EU. 3PL organizations can help SMEs deal with the complex and extensive documentation requirements of the EU, such as labelling, marking and proper packaging. They can also negotiate rates with transportation carriers, organize insurance and provide customs brokerage [10].

Fourth party logistic (4PL) organizations refers to those that provide integrated services for almost the entire supply chain for their customers. 4PL organizations are able to provide services in the product design and development stage, procure and outsource components in the production and manufacturing stage, engage 3PL organizations for the logistics and distribution stage, as well as support customer service and global deployment stages [10].

2.6 Challenges for the Sector

Industry Canada conducted a study on Canada's logistics industry in 2011 and noted that Canada's logistics network performance ranked 14th in the world, primarily due to strengths related to "*timeliness, logistics quality and competence*". However, Canada seems to lag behind in performance related to "*customs clearance and tracking and tracing processes*" [9].

While courier services are generally profitable, sources reviewed as part of this project indicate that the profit margin for the sector is generally low, typically between -1 to 8% (earnings before interest and tax), with freight carriers (2PL) operating at close to 0% margins. The sector was especially hard hit by the financial crisis of 2008, as low cargo volumes cut even further into profit margins.

Carriers are sensitive to fluctuations in the cost of fuel, where increases will further reduce profitability. The price of fuels has been relatively stable over the past few years, however, volatility in the price of oil may cause major shifts in the choice of transportation mode, as well as locations for outsourcing within the supply chain [11].

Carriers are also highly dependent on the efficiency and effectiveness of public infrastructure such as airports, highways, railways and ports, where disruptions such as road congestion and labour disputes at ports directly impact the sector.

The rise in e-commerce is disrupting the sector in a profound manner. The expectations of customers for shipping costs to be cheap, and the method to be on demand, flexible and transparent, is unprecedented. There has also been a shift for the industry to focus resources to better serve the e-commerce segment, rather than brick and mortar stores. Interestingly, as e-commerce giants get larger, some, such as Amazon, begin to acquire their own private transportation fleet, essentially, becoming a 1PL organization. Other competition from "technologically-savvy" newcomers are challenging the traditional business model within the sector [10].

The industry can also be heavily impacted by policy and regulatory decisions. For example the mandated positive train control technology to improve rail transportation safety in the United States has cost the industry billions of dollars in implementation [10].

In addition, the industry remains a labour-intensive one. The recruitment, training and maintenance of a skilled work force continue to be a challenge across the entire sector [10].

Along with transportation, ICT are an enabling factor for globalization and international trade. It also plays an integral role in all five key steps within global supply chains, including product design and development, production and manufacturing, logistics and distribution, customer support and service, and global deployment. As ICT becomes more integrated into businesses activities, this highlights a new vulnerability should the technology fail or become hacked. Breaches in cyber security are costly, both from a liability point of view, as well as from a loss of client confidence point of view. All indications suggest that cyber security attacks are increasing in frequency.

National Research Council of Canada (NRC) conducted a review of research literature between 2013 and 2018, and found that 2,388 out of 5,141 publications discussed challenges faced by the sector. An analysis of the research momentum (the relative velocity of publications in a research area), as shown in

Figure 8, provides a good overview of the challenges within the sector that are currently being examined by the international research community. Table 4 summarizes the same information in a table format, and Table 5 categorizes the challenges into either business level opportunity areas or society level opportunity areas.

Figure 8: Research Momentum related to Challenges within the Sector, 2013-2018 [10]

<table>
<tr>
<td>Challenges with Established R&D
Environmental impact
Inventory control
Greenhouse gases (GHG)
Traffic considerations
Scheduling
Logistic costs
Quality of services
Position tracking</td>
<td>Challenges Currently Garnering Attention in R&D
Decision making
Vehicle routing problem
Customer satisfaction
Risk assessment / management</td>
</tr>
<tr>
<td>New Challenges or Challenges Losing R&D Momentum
Security
Route planning/optimization
Navigation
Logistics efficiency
Time windows
Delays</td>
<td>Challenges Gaining Momentum in R&D
Cost effectiveness
Last mile delivery
Just-in-time
Green logistics
Travel time
Facility locations
Location problems</td>
</tr>
</table>

Table 4: Research Momentum related to Challenges within the Sector, 2013-2018 [10]

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<tr><th>Challenges</th><th>Business Level Opportunity Areas</th><th>Society Level Opportunity Areas</th></tr>
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Route planning / optimization
Navigation
Logistics efficiency
Time windows
Delays</td><td>Security
Route planning / optimization
Logistics efficiency</td></tr>
</table>

Table 5: Challenges Related to Transportation, Logistics and Distribution Classified by Opportunity Areas 2013-2018 [10]

3 Stakeholder Consultations

Select stakeholders from the end-to-end movement of goods along the Canada-European trade corridor were consulted relating to their experience and challenges within the sector. Much of the consultation took place during a research workshop on Transportation and Intelligent Logistics held in Montreal from March 19 to 20, 2019 [12], while other consultations took place via meetings or teleconferences. The list of stakeholders included,

- Transport Canada
- Ports of Montreal and Halifax
- Cargo M (Industry association representing cargo owners and transportation carriers)
- Associated Cargo Specialists (Canada) Inc. (representing 3PL organizations)

Each stakeholder was asked about the portion of the supply chain they are most involved with, what works well within their domain, and where there are key gaps and vulnerabilities. They were also asked about their perspective on research priorities to improve safety, security, efficiency, and environmental sustainability.

Due to the diverse interests of the stakeholders and their respective domains within the end-to-end movement of goods, a variety of gaps, concerns and vulnerabilities were identified. This signals the abundance of opportunities for research to make improvements within the sector. Key gaps and concerns identified by the stakeholders included,

> Transport Canada - *Canada has 550 port facilities, 18 port authorities, 40 federally regulated railways, 26 national airports, 71 regional airports and 1.3 billion kilometres (equivalent) of two-way public roads. Through this system, more than $1 trillion worth of goods move to international markets and the sector supports 1.36 million jobs. Transportation 2030 is a strategic plan for the future of transport that aims for improved traveler experiences, safer transportation, greener and more innovative transportation, world-class waterways and northern transportation infrastructure, and an improvement to trade corridors to global markets.*
>
> The Port of Montreal (POM) - *is the second largest port in Canada, located in the Greater Montreal region. POM provides the shortest direct route from Europe to North America* [13]*. POM has deep connections to other international ports through chainPORT, a partnership of the world leading ports. One of the leading concerns for POM is cyber security. There are three key flows in the end-to-end movement of goods, the flow of capital, the flow of cargo and flow of information. The information sharing tools are currently inadequate in the age of digitization. POM receives information on cyber threats all the time, however the information is fragmented, and not always relevant to the maritime sector. Blockchain may be a solution, and POM is currently working in partnership with Maersk and IBM using the TradeLens blockchain platform in a pilot project. A workshop on cyber security and latest available technologies would be invaluable for POM and the sector.*
>
> The Port of Halifax (POH) - *is one of Canada's oldest ports, situated on Canada's east coast with a natural deep harbour. A priority for POH is digitization, increasing efficiency by transitioning from*

traditional paper based processes to digital processes. POH has plans to create a roadmap of digitization for the port community.

CargoM - *was established in 2012 to "bring together freight transport and logistics stakeholders to promote Montreal as an industry hub"* [14]. *CargoM currently represents 62 members from the import/export industry, transportation sector, industry associations, and academic institutions. For members of CargoM, efficiency is the top priority. Finding bottlenecks within the transportation supply chain and identifying practical solutions are key.*

Associated Cargo Specialists (Canada) Inc. - *is a Canadian-based and owned company that has been in the logistics business for 33 years and specializes in the movement of refrigerated goods. From a SME point of view, there are concerns over blockchain technology, including cybercrime, as well as power outages and information security. As such, there is a need for a human backup. SMEs are also burdened by driver shortages, port congestion, demurrage ("parking fees" that sometimes cost more than the transport itself), detention, and storage and customs inspections.*

4 Analysis

The definition of scientific research in Canada was introduced in 1963 within section 2900 of *the Income Tax Regulations*, and was defined as,

"A systematic investigation or search by means of experimentation or analysis carried out in the field of science, (a) to acquire new knowledge; (b) to devise and develop new products or processes; or (c) to apply newly acquired knowledge in making improvements to existing products or processes" [15].

Thus, R&D can help the sector overcome its challenges, become more efficient and competitive, better meet client needs, manage risk and vulnerabilities, and generate new economic opportunities. An example of research that has already made an impact within the industry is digitization. More digitization within the sector is increasing transparency across the entire sector, reducing inefficiencies, as well as reducing resources and labour associated with manual paper trails [16].

Globally, within the context of transportation, logistics and distribution research, China is the undisputed leader, as shown in Figure 9 with 780 publications. Canada ranks ninth overall.

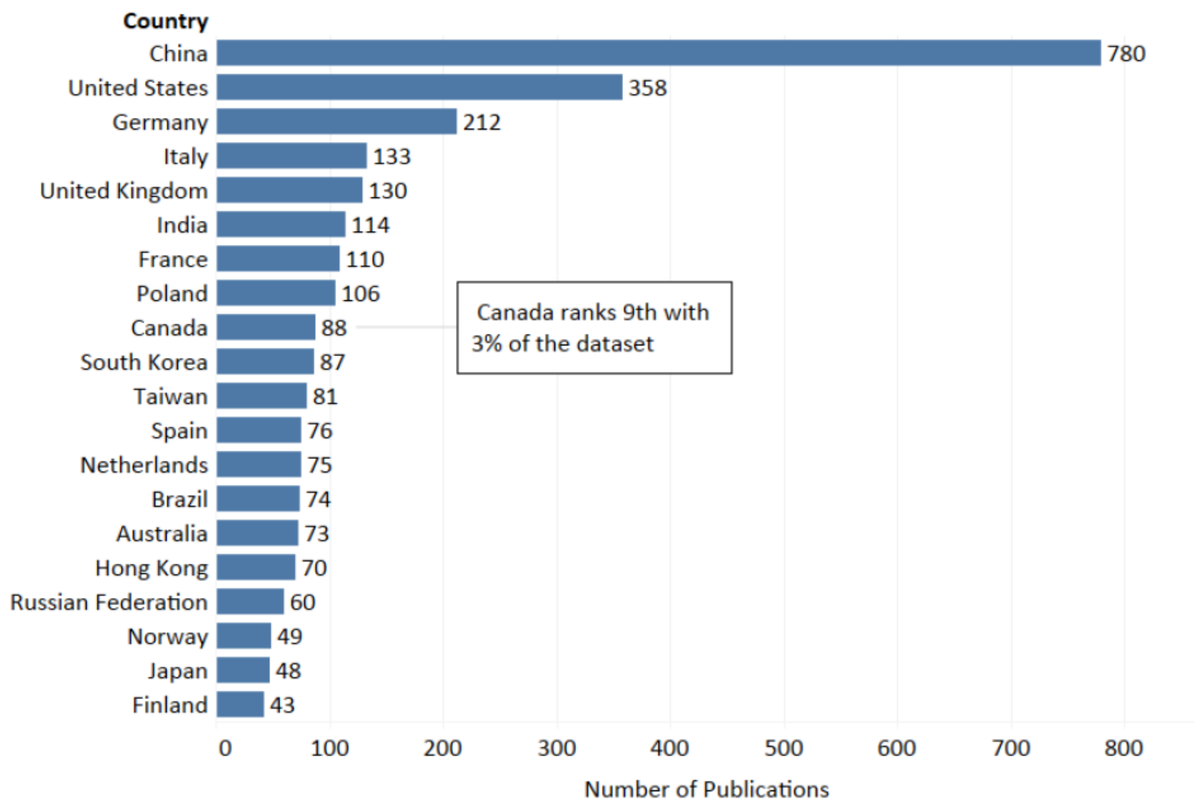

Figure 9: Top Countries for Transportation, Logistics and Distribution Research, 2013 to 2018 [10]

Within Canada, as indicated by publications, Université Laval, Concordia University and Dalhousie University appear to be the leading Canadian research organizations (Figure 10).

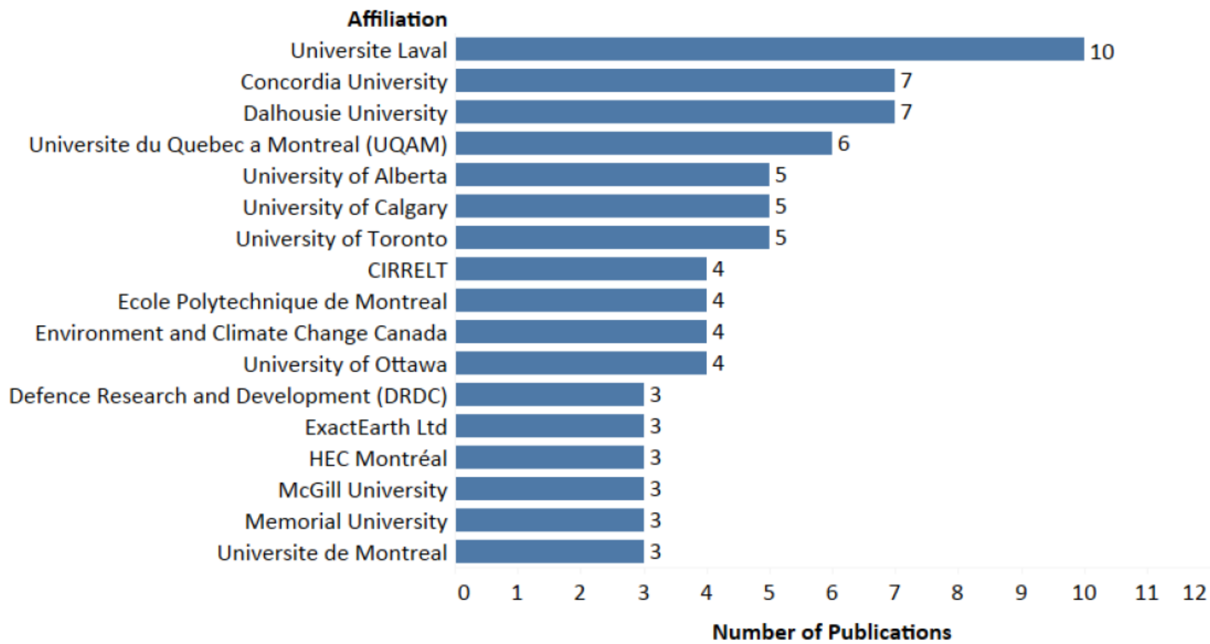

Figure 10: Top Canadian Organization for Transportation, Logistics and Distribution Research, 2013 to 2018 [10]

4.1 Current and Emerging R&D

NRC performed a scan of research literature between 2013 and 2018, and found 43 research areas generated the most publications out of a total of 5,141 publications [10].

An analysis of the research momentum (the relative velocity of publications in the 43 research areas), as shown in Figure 11, provides a good overview of the R&D activities within the sector. Table 6 summarizes the information from Figure 11 in a table format. Table 7 categorizes the research into either business level research opportunity areas or society level research opportunity areas, and Figure 12 illustrates how the research areas are linked to key players within the sector.

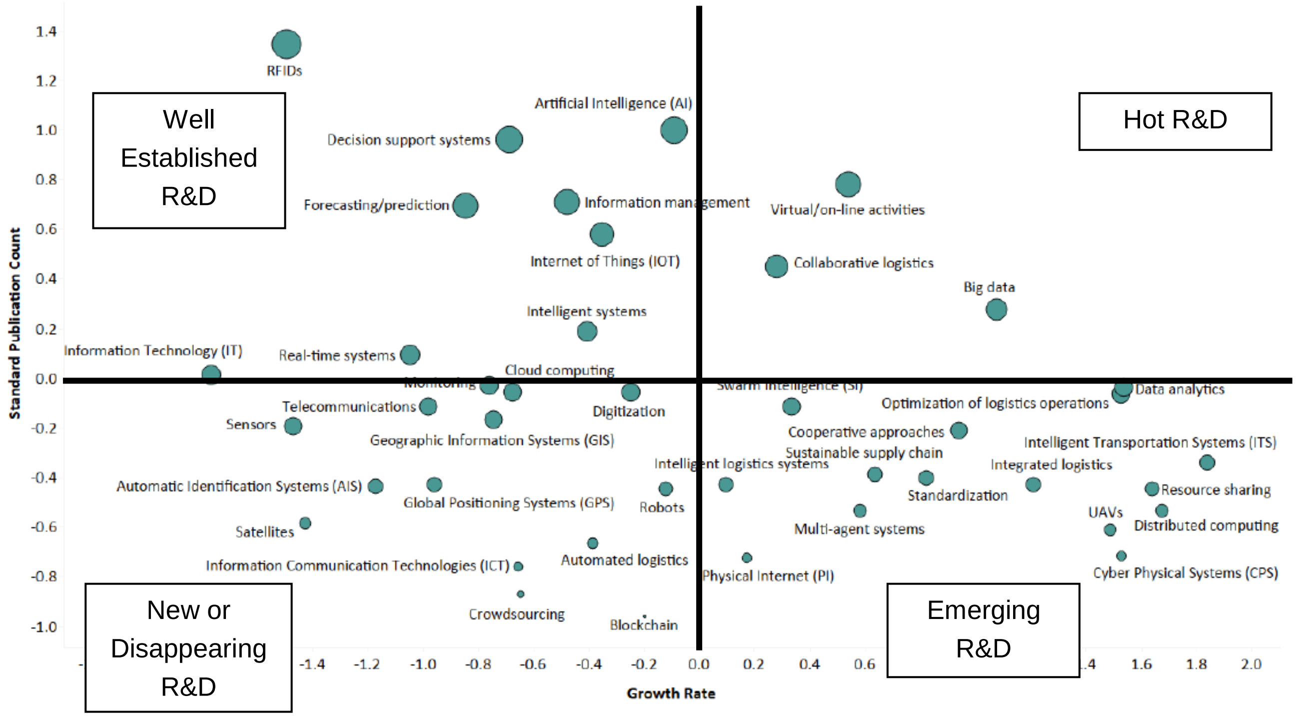

Figure 11: Momentum of Research Areas within Transportation, Logistics and Distribution, 2013 to 2018[3] [10]

[3] The topic area of modeling and simulation was removed from the graph to improve readability. Wireless sensor networks is also appears to be missing from the graph.

Well Established R&D	**Hot R&D**
• Radio-frequency identification (RFID) • Decision support systems • Artificial intelligence (AI) • Forecasting/prediction • Information management • Internet of things • Intelligent systems • Information technology • Real-time systems	• Virtual/on-line activities • Collaborative logistics • Big data
New or Disappearing R&D	**Emerging R&D**
• Monitoring • Cloud computing • Digitization • Telecommunications • Sensors • Geographical information systems (GIS) • Automatic identification systems (AIS) • Global positioning systems (GPS) • Robotics • Satellites • Automated logistics • Wireless sensor networks • Information communication technologies (ICT) • Crowdsourcing • Blockchain	• Swarm intelligence • Physical internet • Intelligent logistics systems • Intelligent transportation systems • Distributed computing • Resource sharing • Data analytics • Cyber physical systems • Optimization of logistics operations • Unmanned aerial vehicles (UAV) • Integrated logistics • Cooperative approaches • Standardization • Sustainable supply chain • Multi-agent systems

Table 6: Momentum of Research Areas within Transportation, Logistics and Distribution, 2013 to 2018 [10]

	Business Level Research Opportunity Areas	Society Level Research Opportunity Areas
Well Established R&D	• Modelling and simulation • RFIDs • Decision support systems • AI • Forecasting/prediction • Information technology & information management • Internet of things • Intelligent systems • Real-time systems	• Modelling and simulation • Decision support systems • AI • Forecasting/prediction • Internet of things
Hot R&D	• Virtual/on-line activities • Collaborative logistics • Big data	• Big data
Emerging Areas	• Swarm intelligence • Physical Internet • Intelligent logistics systems • Intelligent Transportation Systems • Distributed computing • Resource sharing • Data analytics • Cyber physical systems • Optimization of logistics operation • UAVs • Integrated logistics • Cooperative approaches • Sustainable supply chain • Multi-agent systems	• Physical Internet • Intelligent transportation systems • Data analytics • Cyber physical systems • Cooperative approaches • Sustainable supply chain • Standardization
New or Disappearing R&D	• Monitoring • Cloud computing • Digitization • Telecommunications • Sensors • GIS • AIS • GPS • Robotics • Satellites • Automated logistics • ICT • Wireless sensor networks • Crowdsourcing • Blockchain	• Monitoring • Cloud computing • GIS • AIS • GPS • Blockchain

Table 7: Research Related to Transportation, Logistics and Distribution classified by Opportunities

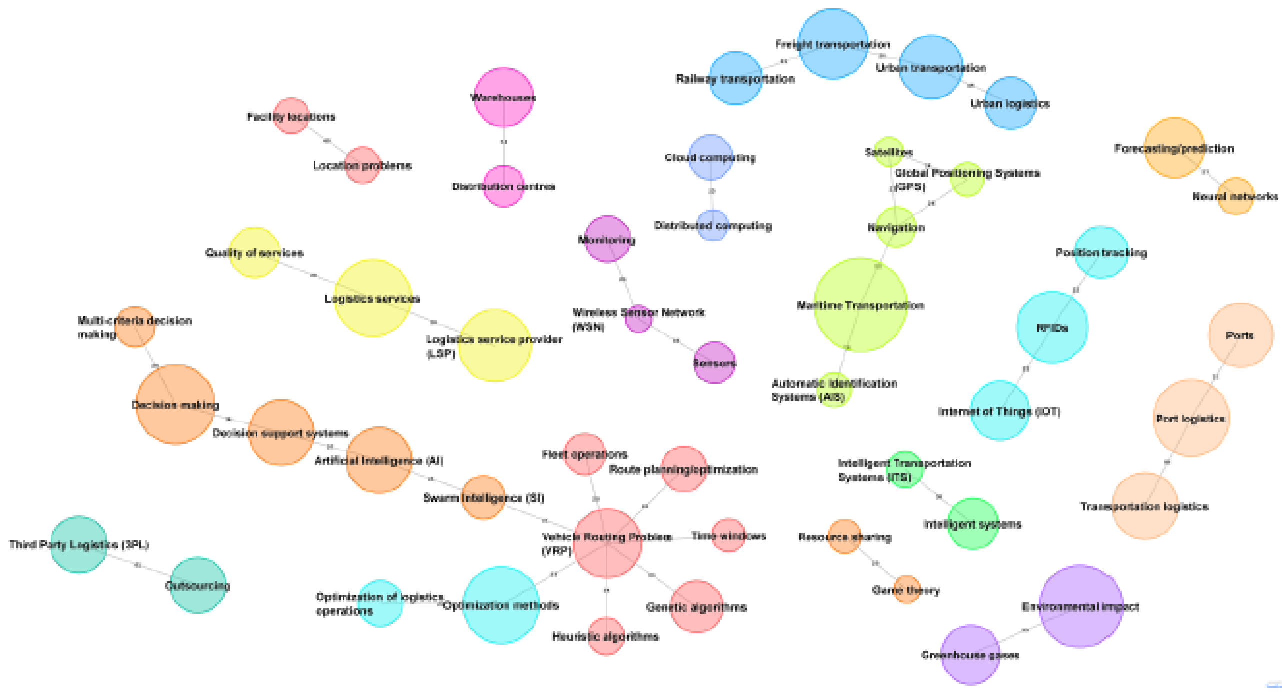

Figure 12: Transportation Logistics Cluster Map [10]

4.2 Key Research Opportunity Areas

Table 7 shows that, of the 43 research areas as identified for the 2013 to 2018, 5141 publication dataset, 39 were considered to provide business level opportunities for further research and 19 were considered to have society level opportunities for further research. The 19 society level opportunity areas were amalgamated into 10 key research opportunity areas as follows:

1. Big data and data analytics;
2. Monitoring, GIS, AIS, and GPS, modelling and simulation, forecasting/prediction, and decision support systems;
3. Artificial intelligence;
4. Blockchain;
5. Cyber physical systems;
6. Physical internet & cloud computing;
7. Intelligent transportation systems;
8. Collaborative logistics and approaches;
9. Standardization, regulations, rules and policies; and
10. Sustainable supply chain.

4.2.1 Big Data and Data Analytics

Increased automation and digitization has resulted in the collection of increasingly large volumes of data across entire supply chains. The information collected can be used to better understand customer expectations, product flow, asset utilization, transportation efficiencies and bottlenecks, driver behavior, fuel utilizations, etc. Big data holds the key to improving efficiencies, reducing cost and improving services across the entire sector [16].

In the research context, big data is the foundation of many of the key research opportunity areas, as shown in Figure 13, including data analytics, monitoring, modelling and forecasting, AI, blockchain and cyber security.

Big data also supports the development in other research areas, as shown in Figure 14, such as standardization and regulations, collaborative logistics, cloud computing and intelligent transportation systems.

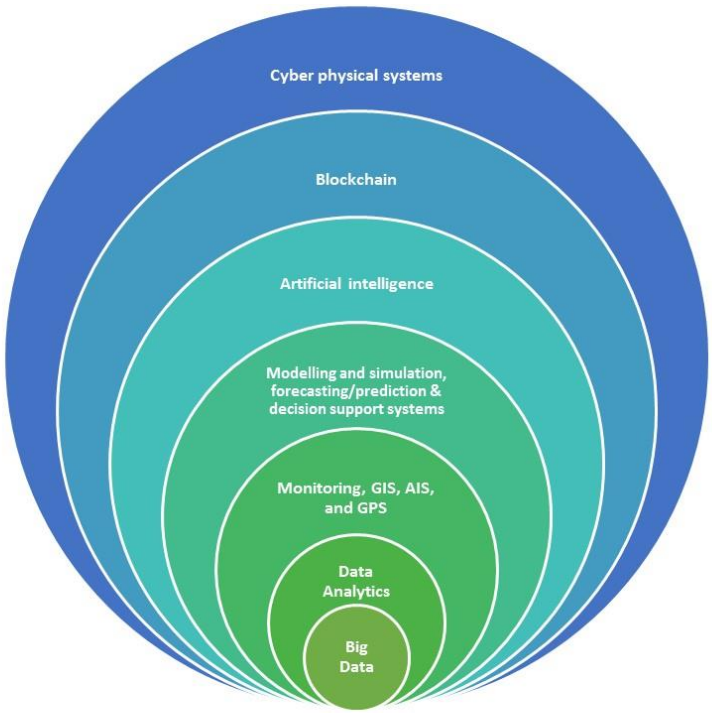

Figure 13: Research Areas with Big Data at its Core

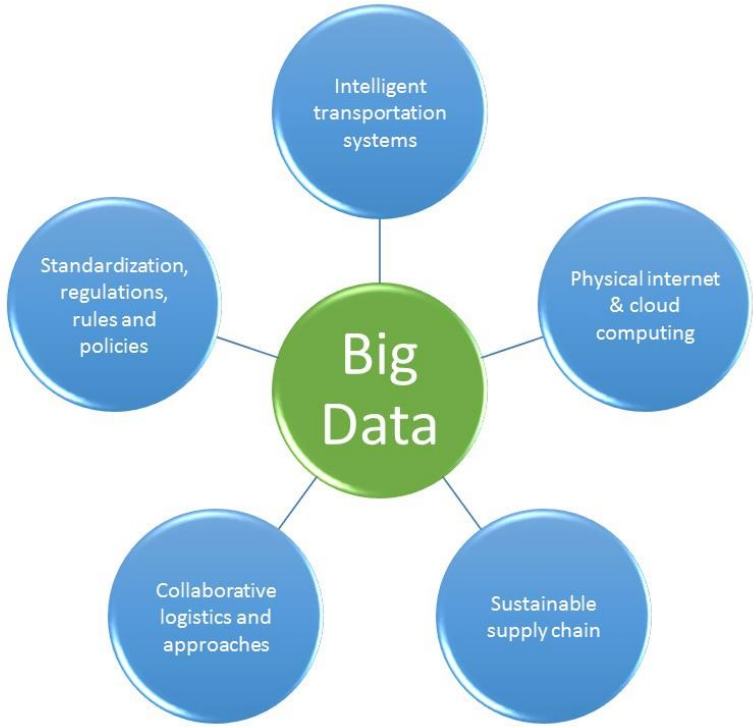

Figure 14: Research Areas Strongly Influenced by Big Data

The quality of outputs and conclusions depends on the quality of the data, therefore, key research questions within big data analytics for the transportation, logistics and distribution sector, includes:

- Identification of types of data for collection;
- Data format requirements;
- Data collection and storage methods;
- Management of increasingly large volumes of data; and
- Data ownership and usage rights.

4.2.2 Monitoring, Modelling, Forecasting and Decision Support Systems

Some of the advice provided by TCS for businesses exporting products to Europe was about proper packing, as there is a high likelihood of rough handing, turbulence, exposure to climatic and temperature extremes during transit, as well as the possibility of theft [2]. In addition, references reviewed as part of this work indicated that while shipping speed and cost are important elements, transparency and reliability are far more valued in some incidences. Depending on the commodity, many organizations are willing to pay extra for the assurance and predictability.

These factors and considerations have led to the monitoring of the goods during transit using sensors and telematics devices, and the tracking of the transportation route using GIS, AIS and GPS technologies, becoming increasingly more common. Technical development has also enabled it to become increasingly more affordable.

Sensors such as RFIDs are being used more and more in the transportation, logistics and distribution sector. RFIDs store digital data in smart labels (or tags), which can be written or captured using radio frequency waves with or without a line of sight. RFID readers can capture data from multiple tags simultaneously [10].

The use of sensors have greatly disrupted the traditional business model within the sector. Increasingly more affordable, they are being used for a wide variety of purposes, including:

- Real time location tracking (e.g. using AIS for maritime transportation, and GPS for ground-based transportation);
- Condition monitoring of goods;
- Climatic and environmental monitoring and controls;
- Monitoring and controls of pressure and gases;
- Measurement of acceleration, altitude and magnetic forces;
- Photo and video imaging;
- Detection of biological and chemical compounds;
- Motion based monitoring;
- Monitoring of inventory; and
- Monitoring of the health of assets.

New sensors such as Apple's iBeacon using Bluetooth low energy, wearable sensors and electronics, and biometric sensors such as facial and finger print identification, voice recognition, gesture controlled, retina scanners, battery free wireless systems, and smart dust, will likely continue the evolution of visibility across supply chain management [10].

On a business level, the data, especially in real time, integrated with GPS, AIS and GIS, enables the tracking of goods, predicts arrival time, enables rerouting based on traffic, provides insight on fleet conditions and driver behavior, improves asset utilization, enables equipment/asset fault identification and health monitoring, increases security, and decreases liability for insurance companies [17]. Telematics devices compliment sensors by transmitting the data.

According to the 2018 Third-Party Logistics Study, 55% of both shippers and 3PL organizations surveyed already use sensors and telematics technologies, as it is seen as giving businesses a competitive advantage by provide vital data for decision making, in addition to providing new business opportunities. The report also indicated that 54% of shippers and 58% of 3PL organizations are planning on investing in the technology in the future [16].

From a national perspective, such data can provide information related to efficiencies across the entire supply chain, including transportation efficiencies across the country, maritime surveillance (AIS), effectiveness of national regulations and policies, efficiencies of transportation infrastructure such as intermodal transfer points, port movements, border wait times, and custom clearance efficiencies. In cases of potential emergencies related to public safety and natural disasters, monitoring and tracking through sensors enables the identification of vulnerabilities, assessment of risk, increased resiliency of critical infrastructure, and facilitate recovery [16].

Key research opportunities within monitoring, modelling and predictive analytics for the transportation, logistics and distribution sector, include:

- Identification of sensors for use in data gathering to assess efficiencies;
- Modelling of transportation routes and corridors for export from Canada to the EU to identify bottlenecks and vulnerabilities; and
- Risk assessment of vulnerabilities related to safety, security (both cyber and physical), efficiency and sustainability.

4.2.3 AI

Big data is enabling businesses to review and analyze historical data to assess current and past performance. Digital technologies are evolving to become more forward looking through the use of modelling and simulation techniques to forecast performance, as well as predict the impact of operational and technological changes. Going forward, the data will be more real-time and impact both short term and long term decisions. The challenge for the industry is to shift focus from simply transferring goods to examining and managing the entire supply chain using modelling and predictive analytics [16]. In other words this means moving towards the realm of AI.

The concept of AI was proposed by John McCarthy in 1959 and has since been imprinted in the public imagination by the Terminator movie franchise. AI is often defined as machines performing functions that mimic human intelligence, especially those related to reason, learning and problem solving [18]. According to a report published by DHL, artificial intelligence is not a single entity, but rather a set of "*interrelated components*" including sensing, processing, learning and improving, as demonstrated by Figure 15.

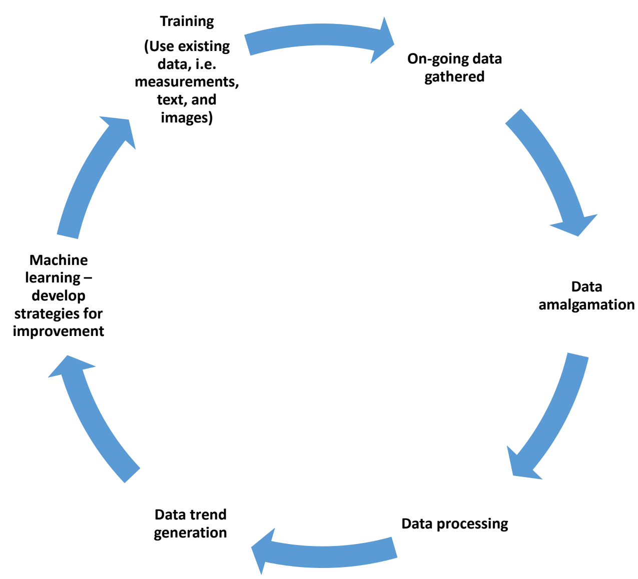

Figure 15: AI Cycle [18]

For the transportation and logistics sector, AI has the potential to further automation. Repetitive and high frequency work are increasingly being replaced by automation, either through robotics or through digital technologies. AI will begin to take over more functions that require human judgement and reasoning, starting with simple and specific types of tasks, then progressing to increasingly complex tasks. AI has the potential of improving efficiency, reducing cost and human errors.

Examples of AI applications within transportation, logistics and distribution, include:

- Warehouse operations – in the future, advanced robotics and AI will be able to identify, locate, load and transport packages within the warehouse, increasing efficiencies and reducing labour costs; [10]
- Quality control inspections – can be made by robots to examine cargo upon arrival at destination;
- Augmenting clerical labour – using software robots integrated into the business and ICT applications thus increasing efficiencies [18]; and
- Using a combination of cameras and sensors to remotely monitor cargo, transportation and infrastructure assets, using AI to identify wear and damage, and recommend repair strategies [18].

Within supply chain management, AI has the potential of deepening the impact of current efforts in modelling, simulation and forecasting, enabling companies to achieve levels of optimization beyond human capacity. In addition, AI enables organizations to use advanced analytical tools to identify, assess and manage risk from spare parts, labour disruptions, transportation accidents, etc. AI is the next step in innovation that will disrupt traditional business models and transform the entire sector from reactive to proactive, from planning to forecasting, and from manual to automatic [18].

Key research opportunities within AI for the transportation, logistics and distribution sector, include:

- Use AI to further the modelling and risk assessment work to identify opportunities to improve safety, security (both cyber and physical), efficiency and sustainability; and
- Use AI at ports and borders to optimize movement, customs inspection and clearance.

4.2.4 **Blockchain**

The concept of blockchain has existed in one form or another since the 1990's. In the transportation, logistics and distribution sector, where the shipment of goods often involve multiple parties with complex relationships and transactions[4], blockchain is the technology that can enable the transparent recording and capturing of all dates, cargo movement, quality, transactions, communications, interactions and relevant data between all parties involved [19].

The structure of blockchain is a decentralized approach, meaning no single entity controls all the data, this type of technology has the potential to increase data accountability, consistency and security, as it is more difficult to alter or corrupt [16].

According to a report on blockchain technologies from DHL, the technology also has the potential to streamline and improve efficiencies within the sector, for example replacing manual paper trails with

[4] For example, a shipment from East Africa to Europe can involve almost 30 people/organizations and more than 200 transactions and communications.

automated processes, as well as eliminating the need for third party intermediaries that currently verify and record transactions, such as brokers, legal and settlement services [19].

This technology also has the potential of disrupting the traditional business model by introducing new services such as the use of cryptocurrency in transactions, and the generation of tamper-proof documents and certificates. In addition, blockchain technologies enables the tracking of a product throughout its entire life cycle (from raw materials, production through to end use), paving the way for environmentally sustainable supply chains, as well as for consumers to be able make purchase choices related to ethical sourcing.

According to the 2018 Third-Party Logistics Study, there are a number of challenges related to blockchain technologies, mostly in terms of standardization, governance and interoperability, as there is a need for the exchange of data across different organizations, platforms and systems [16].

While technology development, and details related to the platform and adoption of blockchain will likely be worked out by industry, there may be the need for the sector to develop standardized approaches and methodologies. This is especially important in consideration of concerns related to litigation and liability, where companies may push back as more data is made available/visible across the supply chain, for fears of being held liable [16].

4.2.5 Cyber and Physical Security

Recent advancements in ICT has given businesses more tools to operate effectively in foreign markets such as the EU. As ICT become more integrated into businesses activities, this highlights a new vulnerability should the technology fail or become hacked. Breaches in cyber security are costly, both from a liability point of view, as well as from a loss of client confidence point of view, judging from recent experiences of Equifax, Bell Canada, Uber and Nissan Canada. All indications suggest that cyber security attacks are increasing in frequency.

The transportation and supply chain sector is particularly vulnerable to cyber-attacks, as the transportation of goods involves communication, data exchange and monetary exchange between many stakeholders. For example, a container shipment may involve the cargo owner, a third party logistics company, distribution centres, at least one surface transportation company, the port of lading, a maritime shipping company, the destination port, the consignee, customs authorities, a dispatch company, data portal intermediary and banks. As a result, cyber-attacks on even one of the organizations could expose all other companies to the same attack, in addition to disrupting the entire integrated supply chain.

Shippers and ports are particularly wary of cyber security related issues, as such issues can impact their ability to manage traffic flow and communicate with fleets, resulting in potential safety concerns.

Since digital technologies are orders of magnitudes more efficient than manual systems of the past, the increased digitization and automation is inevitable and will continue. Canada needs to be better prepared as transportation, logistics and distribution is an essential part of the economy. In addition, there is a need to protect physical assets and the privacy of Canadians.

Key research opportunities within cyber and physical security for the transportation, logistics and distribution sector, include:

- Better understand the history of cyber-attacks, what was done and who were the targets;
- Review and examination of encryption technologies;
- Review and examination of biometric technologies for access control, identification of security breaches, monitoring of high value goods, reduction of forges and fraud [17]; and
- Identification of vulnerability and bottlenecks.

4.2.6 Physical Internet & Cloud Computing

The internet as we know it, is a global network that connects devices that use the internet protocol suite (TCP/IP) through fibre optic and wireless technologies. Connectivity and the speed of connectivity for devices has been increasing at a rapid rate over the past few decades. In the case of cellular connectivity, the evolution has progressed from first generation (1G) wireless technology to the current fourth generation (4G). In the US, service providers such as AT&T are currently developing infrastructure for fifth generation (5G) wireless technology. The roll out of 5G networks in Canada will be slower than in the US, as the auction for the needed 3,500 MHz spectrum has been delayed at the time of writing.

5G networks have the potential to revolutionize the sector. 5G will be faster, more responsive and will be able to connect more devices. Currently wireless connectivity is expensive, especially in Canada (in part due to the limited capacity of 4G systems), resulting in the prevalent use of Wi-Fi, which is not always feasible for the transportation, logistics and distribution sector.

5G networks are more able to accommodate devices and sensors, and facilitate the real-time sharing of large datasets [18]. In transportation, logistics and distribution, this means more remote monitoring and surveillance applications, more tracking and tracing, greater automation in ports and intermodal transfer locations, greater automation and robotics, and driverless vehicle technologies, etc., potentially at a lower cost.

Cloud computing is also transforming the industry by providing businesses access to remotely hosted data and solutions (via the cloud), thus reducing the need and cost of investing in physical computing infrastructure [9]. Cloud computing provides the foundation and infrastructure for the deployment of technologies with big data at its core, such as blockchain.

With more connectivity, more devices, more monitoring and control, more datasets stored and accessed through the cloud [18], comes more opportunities for research.

Key research opportunities within physical internet and cloud computing for the transportation, logistics and distribution sector, include:

- Better understand the full capabilities of 5G and the roll out schedule in Canada;
- Determine how to best utilize 5G for the sector; and
- Pilot the use of 5G in applications.

4.2.7 **Intelligent Transportation Systems**

Intelligent Transportation Systems (ITS) is considered to be another set of interrelated technologies used in transportation, with the goal of improving safety, efficiency and experience, for passenger travel and for the movement of goods. Existing NRC research programs examine this research area in depth, and as a result, this paper will not go further into the subject.

4.2.8 **Collaborative Logistics and Approaches**

While companies generally form working partnerships at a local level, on a national level the sector is highly fragmented. There are companies of varying sizes from international corporations through to SMEs.

In Canada, as shown in Table 3, in 2017, there were 46,120 business locations for trucking, 8,824 for support activities for transportation, 3,185 for courier and messenger services, and 2,817 for warehouse and storage, in addition to business locations related to rail, marine, and air modes of transportation. More often than not, the organizations use technologies that are not compatible with each other.

For a country as geographically large as Canada, more collaboration on a national level related to operational activities, R&D, technological adaptation and uptake, have the potential to increase efficiency of the sector as a whole, reduce barriers and cost, and increase sustainability [10].

Key research opportunities would be the facilitation of collaborative logistics and approaches for the industry, especially related to tackling tough challenges and promoting innovation and technological adoption. Some potential initiatives include:

- The last mile problem - the cost of long haul transportation (marine and rail) is relatively low compared to the so called “last mile” of shipment. The cost of transportation increases the closer it get to final destination, such that from the final distribution centres to end users can be as much as 25% of the cost of the entire shipment. This is seen as an industry wide issue that will benefit from a collaborative approach to last mile delivery, as well as technological innovations such as mobile robotics, or digital applications for common warehousing [10]; and
- Technological adaption - sources reviewed as part of this work indicate that the sector has been slow to adapt to technological innovations and that “*manual data entry is commonplace*” [10]. Innovation and technology has the potential to transform the industry. Promotion of technology uptake potentially through annual workshops would help the industry to better understand and be exposed to new developments, connect with partners and collaborators, as well as facilitate pilots and demonstration projects.

4.2.9 **Standardization, Regulations, Rules and Policies**

Many of the research papers reviewed as part of this work discussed the importance of standardization within the sector, since the industry is complex with many players of differing sizes, but have the need for interoperability, especially in the case of blockchain.

A key research opportunity within standardization for the transportation, logistics and distribution sector, is the facilitation of the standardization in technological development, utilization, big data collection and dissemination.

4.2.10 Sustainable Supply Chain

According to data from Environment and Climate Change Canada, in 2016, the transportation sector was the second largest source of GHG emissions in Canada, accounting for 25% of the total national emissions [20]. In addition, the sector is responsible for emitting substantial air pollutants including carbon monoxide, nitrous oxide, volatile organic compounds, sulfur oxides and ammonia. Ocean going vessels have also been found to introduce invasive species such as zebra mussels that have altered the ecology of different regions.

Technologies and methods to reduce energy consumption, improve vehicle emissions, increase fuel efficiency and reduce environmental footprints would significantly improve the sustainability of freight transportation and that of the entire supply chain.

The end-to-end movement of goods is extremely complex. In order to fully understand the magnitude of the impact on climate change and air pollution, there is an opportunity for research to:

- Develop blockchain-like solutions to track emissions for the entire product life cycle;
- Promote the use of monitoring and tracking technologies for route optimization;
- Support and promote the development of technologies that increase efficiency, reduce emissions and fuel consumption;
- Develop and deploy solutions to reduce the environmental footprint and cost related to “last mile delivery”, include collaborative delivery approaches, depot for customers to pick up, electric delivery vehicles, etc.; and
- Use AI to further the modelling to identify opportunities to improve sustainability.

5 Conclusions and Recommendations

Since the signing of CETA in 2016, Global Affairs Canada identified twelve key sectors that will benefit from opportunities created by this trade agreement, where Canadian businesses will likely begin to export to Europe or will increase exports to Europe in the coming years, including aerospace, agriculture and agri-food, automotive, clean technologies, fish and seafood, forestry and wood products, ICT, infrastructure, medical devices, metals, mining and minerals, oil and gas, and pharmaceuticals.

The objective of this project is to examine the movement of goods between Canada and Europe, to better understand key players, the transportation equation, challenges and bottlenecks, and opportunities for R&D to improve safety, security, efficiency and environmental sustainability.

A literature review was completed, along with consultations with a select number of key stakeholders within the end-to-end movement of goods between Canada and the EU. NRC also completed a scan of research literature (5,141) of the transportation, logistics and distribution sector between 2013 and 2018. 19 research areas (amalgamated into 10 key research opportunity areas) were considered to have society level opportunities for further research, 9 of which are shown in Table 8. The research opportunity area related to ITS has been omitted because existing NRC research programs have examined those opportunities in depth.

The importance of the Canada-EU trade corridor and the significance of CETA for the Canadian economy cannot be understated. Therefore, a key recommendation from this work is to incorporate elements of the key research opportunities highlighted by Table 8 into future NRC research priorities, agendas and activities related to transportation, logistics and distributions, in order to address some of the gaps and challenges of the sector.

Key Research Opportunity Areas	Key Research Opportunities
Big data and data analytics	• Identification of types of data for collection • Data format requirements • Data collection and storage methods • Management of increasingly large volumes of data • Data ownership and usage rights
Monitoring, modelling and predictive analytics	• Identification of sensors for use in data gathering to assess efficiencies • Modelling of transportation routes and corridors for export from Canada to the EU to identify bottlenecks and vulnerabilities • Risk assessment of vulnerabilities related to safety, security (both cyber and physical), efficiency and sustainability
Artificial intelligence	• Use AI to further the modelling and risk assessment work to identify opportunities to improve safety, security (both cyber and physical), efficiency and sustainability • Use AI at ports and borders to optimize movement, customs inspection and clearance
Blockchain	• Development of standardized approaches and methodologies across the sector
Cyber and physical security	• Better understand the history of cyber-attacks, what was done and who were the targets • Review and examination of encryption technologies • Review and examination of biometric technologies for access control, identification of security breaches, monitoring of high value goods, reduction of forges and fraud • Identification of vulnerability and bottlenecks
Physical internet & cloud computing	• Better understand the full capabilities of 5G and the roll out schedule in Canada • Determine how to best utilize 5G for the sector • Pilot the use of 5G in applications
Collaborative logistics and approaches	• The last mile problem • Promotion of technology uptake
Standardization, regulations, rules and policies	• Facilitate the standardization in technological development, utilization, data collection and dissemination
Sustainable supply chain	• Develop blockchain-like solutions to track emissions for the entire product life cycle • Promote the use of monitoring and tracking technologies for route optimization • Support and promote the development of technologies that increase efficiency, reduce emissions and fuel consumption • Develop and deploy solutions to reduce the environmental footprint and cost related to "last mile delivery", include collaborative delivery approaches, depot for customers to pick up, electric delivery vehicles, etc. • Use AI to further the modelling to identify opportunities to improve sustainability

Table 8: Summary of Key Research Opportunity Areas for the Transportation, Logistics and Distribution Sector

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