Strategy for the Development of Quebec's Artificial Intelligence Ecosystem

Artificial Intelligence Cluster Steering Committee

A mandate from

Économie, Science et Innovation Québec

May 2018

FINAL VERSION

Université de Montréal's role

In March 2017, the Quebec government mandated the Université de Montréal to set up a Steering Committee to develop the strategy for the development of Quebec's artificial intelligence industrial and scientific cluster. This Committee was to submit its recommendations on the development of the cluster's resources regarding the attraction of international experts, the availability of computing resources, the conditions most favourable for industrial collaborations and the hiving-off of companies, as well as human resource training and development. In addition to developing a strategic development plan, the Committee was to liaise with relevant federal government bodies, the Canadian Institute for Advanced Research (CIFAR) and the Canada First Research Excellence Fund and encourage future private and public investments.

The Université de Montréal was also mandated to set up a Quebec Artificial Intelligence Institute as a separate non-profit entity. Moreover, this Institute should be able to foster the partnerships needed to fund its activities, while addressing the economic issues and social transformations resulting from the AI-driven digital revolution.

Université de Montréal

Co-Chairs' message

The Artificial Intelligence Cluster Steering Committee (hereinafter, the Steering Committee) was constituted in May 2017 and has as its mandate to position Quebec as a leading player in artificial intelligence (AI), through research and innovation, business creation or application deployment within its industrial structure. One year later, in the wake of a series of impactful events, the Committee and its 12 members present the fruit of their reflections, research and analysis in this *Strategy for the Development of Quebec's Artificial Intelligence Ecosystem*.

In the past few years, Quebec has experienced a historic boom in artificial intelligence, thanks to the excellence of academic research in the field that has led to the arrival on the scene of technology giants, the rapid proliferation of Quebec start-ups and the establishment of renowned research institutes. Quebec can now rely on its strengths to drive the development and growth of a rich and dynamic artificial intelligence ecosystem that will be the envy of its international peers. While this strategy does not presume to solve all the present or future challenges ecosystem stakeholders will face, we are convinced that it will help the government shape a prosperous future for Quebec in artificial intelligence.

Twelve recommendations that fall into five strategic approaches lie at the core of this strategy. These are to ensure the growth and sustainability of Quebec's artificial intelligence (AI) academic research cluster, develop digital science talent to meet Quebec's needs, accelerate the adoption and development of AI solutions by the entire economic fabric of Quebec, develop an international responsible AI hub in Quebec and, finally, support the development of ecosystem support structures.

We would like to extend our sincere thanks to the Steering Committee members and observers for their dedication, and also thank all the advisors, staff and experts we consulted who have generously agreed to participate in this exercise. The Steering Committee and its members will now turn their attention to the implementation of the recommendations, as they are confident that the recommendations will enable Quebec to become a world leader in artificial intelligence.

We also wish to acknowledge the strong vision the government has wisely outlined for this forward-looking sector and feel certain that, thanks to continued and targeted government support, the best outcome for the benefit of the greatest number is assured.

Pierre Boivin

Guy Breton

May 2018

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Introduction

Foreword

1. Steering Committee mandate

For some years, Canada, and more particularly Quebec, has experienced a never-before-seen effervescence in the artificial intelligence (AI) sector. As shown in Figure 1, technology giants like Google and Facebook have opened AI labs in Montreal, start-ups like Element^{AI} have raised impressive amounts of private funding and research institutes have rallied around Quebec's historical strengths.

The current generalized effervescence is rooted in the university environment, a sphere where Quebec stands out on the world stage. It is also due in part to the support the Canadian Institute for Advanced Research (CIFAR) provided in 2004 for Yoshua Bengio's creation of the Machine Learning Program. [1] As another proof of the excellence of Quebec's endeavours in AI, the federal government awarded a $93.6M Canada First federal grant to the Institute for Data Valorization (IVADO) – a group of 1,000 data science, operational research and artificial intelligence scientists – in the fall of 2016.

The Quebec university milieu, from France's perspective

Cédric Villani's recent report to the French government states that Quebec currently "has, with the City of Montreal, the largest concentration of AI researchers—250 doctoral researchers at McGill and the Université de Montréal—who also benefit from a large cohort of roughly 9,000 AI students in computer science (6194), computer science and computer engineering (1149), mathematics (1360), applied mathematics (113) and probabilities and statistics (141) programs."[2]

In March 2017, the ministère de l'Économie, de la Science et de l'Innovation (MESI) choose to support the acceleration and optimization of development of Quebec's AI ecosystem with a total of $100M over a five-year period. At the same time, it gave the Université de Montréal the mandate to form a Steering Committee to identify the measures needed to leverage this major investment to strengthen the competitive advantage in AI Quebec has gained thanks to the university sector.

The MESI tasked the Artificial Intelligence Cluster Steering Committee with four missions:

1. Ensure the launch of the Quebec Artificial Intelligence Institute.
2. Develop a strategic plan for the creation of the AI cluster by 2018-2022.
3. Study the ethical, economic and social impacts of AI.
4. Take a leadership role in defining a pan-Canadian AI strategy.

In September 2017, the Conseil consultatif sur l'économie et l'innovation (CCEI) has praised the Quebec government's focused ambition to see AI become a real driver of Quebec's economy. In its report, the

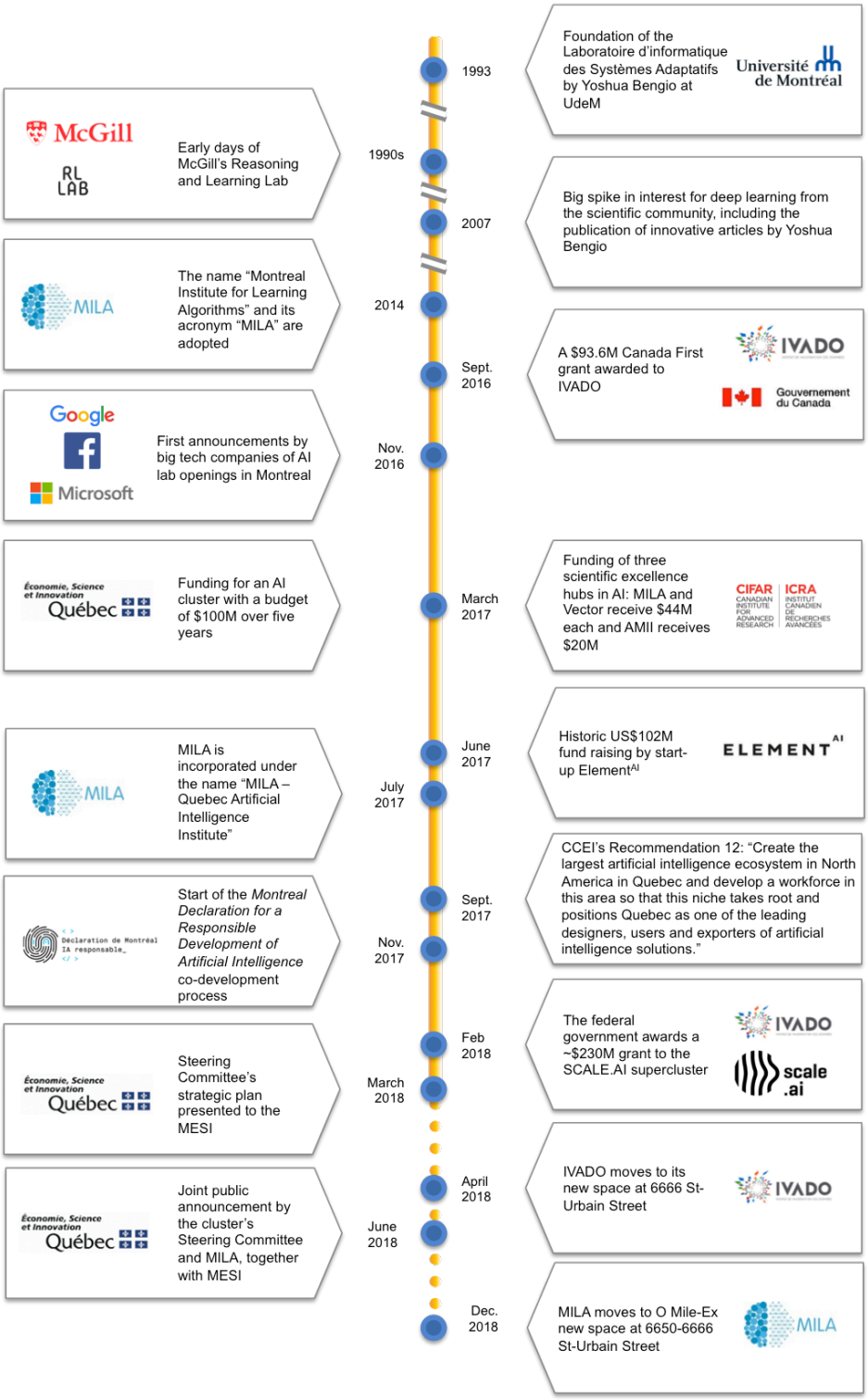
[1] CIFAR also spearheaded Canadian and global AI research by supporting the work of Geoffrey E. Hinton, Professor of Computer Science at the University of Toronto, in the 1980s.

[2] See https://www.tresor.economie.gouv.fr/Articles/28619068-9771-411c-9a43-20fdaeb0adc8/files/5a885cf0-0af1-4243-be03-8857b5319fae, webpage visited on April 30, 2018 (as were all the pages referenced in this document).

CCEI urged the government and ecosystem stakeholders to push even further to "create the largest artificial intelligence ecosystem in North America in Quebec and develop a workforce in this area so that this niche takes root and positions Quebec as one of the leading designers, users and exporters of artificial intelligence solutions." (translated from the French original)[3]

[3] See http://www.ccei.quebec/fr/rapport-integrateur.

Figure 1 – Chronology of Quebec AI ecosystem structuring events



More of an ecosystem than a cluster…

The term "cluster" has often been used to describe the AI ecosystem developing in Quebec. To avoid any confusion with industry clusters – which are sector specific (e.g., Aéro Montreal for the aerospace sector) – we recommend using the expression "AI ecosystem." Indeed, AI will be used in all industrial sectors and become a ubiquitous technology. As a result, close collaboration between existing Quebec industrial clusters and the AI ecosystem is advocated.

2. Last year's achievements

This report is the Steering Committee's response to the second of the four requests the MESI made in spring 2017.

Before presenting the Quebec AI ecosystem's development strategy, it is important to mention how the Steering Committee addressed the MESI's three other requests.

Initially, the Steering Committee was tasked with ensuring the **launch of the Quebec Artificial Intelligence Institute**. The creation of this entity progressed apace, and, in July 2017, the MILA – Quebec Artificial Intelligence Institute was set up as a not-for-profit organization (NPO). This institute is the result of a collaboration between the Université de Montréal and McGill University and also has close ties with Polytechnique Montréal and HEC Montréal. Work to secure proper governance for the Institute is underway, and its board of directors should be fully constituted shortly. Although it is now an NPO, the MILA – Quebec Artificial Intelligence Institute intends to honour its commitments to IVADO and the Canada First Research Excellence Fund.

The organization's mission extends beyond its university vocation and includes the following elements:

a. **Training** – In collaboration with universities and associated educational institutions, train, attract and retain machine learning talent.
b. **Academic research** – In collaboration with universities and associated educational institutions, contribute to basic research by building on its strengths in deep learning and reinforcement learning.
c. **Technology transfer** – Contribute to the economic development of Quebec through technology transfer and business innovation.
d. **Social dialogue** – Promote the responsible use of artificial intelligence as well as social dialogue regarding issues related to it.

The MILA – Quebec Artificial Intelligence Institute will also be one of the main attractions of the new innovation hub in the process of being set up in one of Montreal's emerging neighbourhoods. The space in question is located in a complex called "O Mile-Ex" at 6650-6666 St-Urbain Street and will be home to researchers from various sectors, IVADO, company laboratories, start-ups and venture capital investors. It will bring together various stakeholders in a single place, which is a crucial step in creating a true innovation ecosystem on the ground. The proximity of the different stakeholders will create an environment conducive to collaboration, innovation and technology transfer. Many AI ecosystem stakeholders have already confirmed their presence either in the neighborhood or in the complex itself,

or expressed their interest in setting up shop there, including Element[AI], Quantum Black, Thales and the RBC Institute for Research, Borealis AI.

The Steering Committee was mandated to **study the ethical, economic and social impact of AI**. It should be noted that Quebec has already positioned itself as an active player in the design and use of responsible AI. The *Montreal Declaration for a Responsible Development of Artificial Intelligence* co-development process was launched on November 3, 2017 at the "Forum AI responsable" held at the Palais des Congrès in Montreal. This process aims to generate public debate and propose a progressive and inclusive orientation for the development of artificial intelligence. The first step in the public consultation process that will lead to the publication of the *Declaration* in December 2018 essentially ended in April.

The Steering Committee was also tasked with **taking a leadership role in defining a pan-Canadian strategy for artificial intelligence**. The Steering Committee fulfilled this task by supporting the creation of the Canadian AI Consortium (CAIC), which brings together the MILA – Quebec Artificial Intelligence Institute, Ontario's Vector Institute and Alberta's AMII Institute. The mission of this consortium is to exchange best practices in AI, ensure synergy between the three organizations and formulate common requests to the federal government, such as those related to Canadian computing infrastructures. In the future, members of the consortium will be able to join forces to establish Canada as an international leader in AI versus competitors with greater financial resources. The Canadian Institute for Advanced Research (CIFAR) has also promoted the Canada-wide strategic effort in artificial intelligence by awarding a $125M grant to these three institutes, including $44M to MILA – the Quebec Artificial Intelligence Institute.

Finally, the last year's achievements include the creation of SCALE.AI supercluster thanks to federal and Quebec funding. This consortium—whose operation will be based on collaborations between two academic leaders (IVADO in Quebec and the University of Waterloo in Ontario) and organizations that will work closely with Quebec start-ups in AI (such as the Creative Destruction Lab and NextAI)—will shape "a new global supply-chain platform, strengthen Canada's artificial intelligence (AI) leadership, and accelerate industry adoption of AI-enabling technologies through collaborative and innovative projects." (translated from the French original)[4]

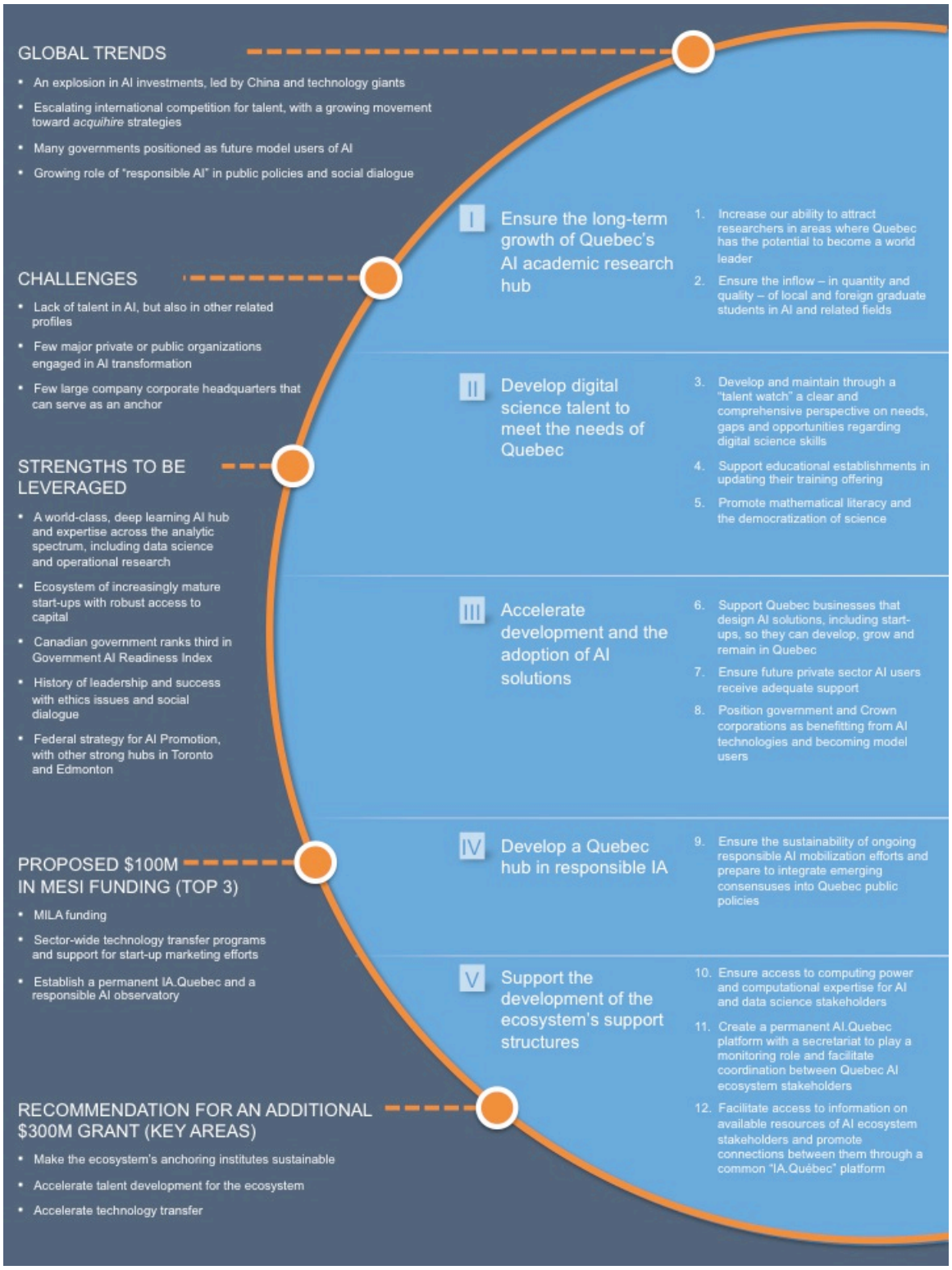
SCALE.AI supercluster announcement

In May 2017, the federal government held a national business-led innovation supercluster competition. The SCALE.AI (Supply Chains and Logistics Excellence.AI) supergroup, led by AI leaders IVADO and the University of Waterloo, was selected.

The federal government will allocate $234M to this supercluster, while the Quebec government has announced an investment of $60M in its 2018-2019 budget. Taking into account the close to $700M in commitments of the participating companies, this structuring project represents a total investment close to $1B.

[4] See https://aisupplychain.ca/fr/.

Report Summary



Overview

Artificial intelligence (AI) is poised to transform Quebec's economy in a radical way over the next few years. Artificial intelligence applications, such as voice recognition and image processing, are already widespread in the service industry and continue to gain ground. For its part, the manufacturing industry is on the cusp of a profound transformation with AI as one of the main drivers. From predictive maintenance to real-time chemical process efficiency optimization, AI applications will gradually but inevitably help our industries to do more with less.

In its 2017 report, the Conseil consultatif sur l'économie et l'innovation (CCEI) has identified the development of AI as one of Quebec's 12 priorities, citing the province's "scientific leg up" and extraordinary potential for implementing AI solutions. This comparative advantage, mentioned and explained in many reports, is based on three main pillars: basic AI research, massive data valuation and applied research.

Indeed, one of the largest cohorts of AI researchers in the world is currently in Quebec. These researchers are very prolific (having published more than 2,000 articles in the past five years), and their writings have an international influence (in the field of deep learning, some have been cited several thousand times). Also of note, more and more students likely to engage in AI research in the future are enrolling in Quebec educational institutions. As an example, at the École de technologie supérieure du Québec and Polytechnique Montréal, there are twice as many students in information technology as there were five years ago.

However, Quebec's strategic positioning is not limited to research. The province, and more specifically Montreal, also has a critical mass of start-ups, investors, potential users, granting agencies and liaison and transfer organizations. These stakeholders form a dynamic and complex ecosystem that extends well beyond university walls and have attracted $150M in AI venture capital over the past two years. They have also spurred large companies like Thales or Microsoft to open seven AI research centres in recent months.

However, the Quebec AI ecosystem also has some weaknesses, as shown in the table below, which the Steering Committee drew up after preliminary benchmarking work. Often, coordination between universities and industry stakeholders remains difficult. For example, companies report that they do not which door to knock on to undertake a collaborative applied research project. Similarly, in Quebec, as elsewhere, the industry's high wages encourage professors who are in a position to train future generations of AI researchers to leave academia to pursue a career in business. For their part, AI producers sometimes have a difficult time finding their first Quebec customers (among other reasons, because large firms are relatively rare in the province), who would serve as a springboard for accessing foreign markets. As for potential AI users, they often misunderstand the technology's potential and impacts in creating a new business model or improving their processes.

Therefore, vigorous action is required to ensure Quebec's competitive edge is maintained over the long term in the face of international competition. And, acting quickly is essential!

Strengths and weaknesses of Quebec AI ecosystem stakeholders[5]

Training and research	Industrial fabric	Support ecosystem
✚ **Advanced expertise** beyond McGill and UdeM	✚ **Recent fundraising of high-profile start-ups** in AI, with a total of ~$150M over the last two years	✚ **Maturity of Quebec VCs and interest** in AI-enablement investment
✚ Presence of **sectoral forces** specific to each university on which to build and **create a potential for specialization**	✚ **Great effervescence in Montreal** created by the establishment of seven research centres by tech giants	✚ Presence of a vast provincial network of **historical stakeholder in technology** transfer to **SMEs**, e.g., Transtech, CEFRIO and CRIM
✚ **Increase in the quantity and quality of talent** universities hire, e.g., at the ÉTS and Polytechnique, twice as many IT students over five years	= **Ecosystem of well-connected clusters**, but whose role vis-à-vis the AI cluster remains to be defined on an individual basis	✚ Presence of **multiple stakeholders** at the forefront of analytic and digital **transformation implementations** in large enterprises, e.g., Accenture, McKinsey, Deloitte
✚ Proactivity of academic stakeholders, e.g., ongoing revision of AI-related programs	– With the exception of big tech companies, **increasing difficulty** in hiring **IT talent**	= Academic institutions have integrated structures to **accelerate technology transfer**, although the format needs to be clarified
= Despite existing collaboration, there's an opportunity to further improve **coordination between universities and industry stakeholders**	– Emerging level of interest in **Quebec's large non-tech firms**, but **lack of understanding** of the potential for short-term value and transformation of longer-term business models	– The **striking force remains limited** in technology transfer to **SMEs**
– **Difficulties** in **attracting academic talent** due to a lack of financial resources and the job framework	– **Few companies/anchoring organizations** that can serve as a first client	– **Technological transfer** capacity distributed over **multiple stakeholders**, e.g., Aligo, Univalor, with links that are more or less close to universities
– High risk of losing the historical competitive advantage, with a **small pool of talent that can be easily destabilized. Ecosystem fears regarding tech giants**	– **Insufficient growth capital**	– Lack of **growth funding** for future successful start-ups
– **No links** between university education, college training and industry needs		
– **Rapid increase in the number of stakeholders and alliances** inside and outside Quebec		

[5] See Artificial Intelligence Cluster Steering Committee, *Balisage de l'écosystème québécois en IA,* Montreal, 2018, starting on p. 66.

Other jurisdictions have announced significant contributions to the development of AI. For example, consider the following facts

- China has declared its intention to become the world leader in AI by 2030. This plan is already being compared to the country's 2014 national strategy on semiconductors, to which Beijing allocated US$15B a year over a 10-year period.[6]
- Singapore has created two organizations – AI Singapore and the Singapore Data Science Consortium – to boost its AI expertise and better coordinate its academic and industrial strengths (the first entity has already received US$115M in funding over five years).
- Finland announced the launch of its "AI Business" program, with a budget of US$250M over four years, to financially support start-ups, SMEs and large companies in the development and use of AI.
- In March 2018, France announced its decision to invest ∋1.5B by 2022 to create artificial intelligence research chairs, significantly increase the number of AI students and achieve major projects in the field.
- Britain hopes to add £630B to the total size of its economy by 2035 by injecting £300M into AI research, matching business AI investments in sectors such as agriculture and life sciences and adopting other measures.

States are also taking non-financial measures to become more competitive in AI. Many of them have equipped themselves with the means to quickly leverage their data. Finland has set up a public data use initiative, emphasizing data use rather than protection, which is a complete paradigm shift.

The Quebec government has far from stood still in the face of these global developments, as evidenced by the list of direct and indirect AI investments it has made in the last year. In its *2018 Economic Plan* and other instruments, the government has, in addition to the $100M over five years reported by the Steering Committee in this report, already invested or announced that it will invest $102M in AI projects or programs, as follows:

- $60M over five years to SCALE.AI for the implementation of this supercluster's projects
- $10M over five years to help launch Creative Destruction Lab of Montreal and NextAI, two centres whose mission will be to help start-ups specialized in AI develop and support students, professionals and entrepreneurs who wish to develop ideas that rely on the use of AI
- $5M to help establish a new international AI organization in Montreal
- $1M so applied mathematical science can be leveraged to support AI-related fields in Quebec
- $12.5M to improve the state-of-the-art computing infrastructure available to the Quebec AI field and other sectors
- $5M for IVADO to carry out a Canada First research project on big data, as well as to increase the state-of-the-art computing power available to researchers
- $8.5M to support collaborative AI research projects through Prompt.

The government has also announced plans to make further major investments that could potentially have an impact on the development of the AI ecosystem. Thus, the *2018 Economic Plan* provides for investments of:

- $15M to encourage digital ownership by tourism industry stakeholders
- $23M to the CRIQ (Centre de recherche industrielle du Quebec) to ensure the transition of manufacturing companies to Industry 4.0

[6] See https://www.cfr.org/blog/chinas-artificial-intelligence-strategy-poses-credible-threat-us-tech-leadership.

- $60M over two years in calls for projects for industry members to use technologies such as AI to meet the challenges facing the industry, test new business models, market new services, etc.
- $47M to increase the graduation rate in key areas, such as science and applied mathematics, for the development of AI in Quebec.

In conclusion, to lead the international race currently in full swing and achieve the goal of creating “the largest artificial intelligence ecosystem in North America” (Recommendation 12 of the CCEI report), Quebec will need to focus its resources on the strategic levers at its disposal. Three imperatives lie at the heart of the strategy outlined herein.

1. We must guarantee the positioning and empowerment of the MILA – Quebec Artificial Intelligence Institute, an epicentre in machine learning whose mission covers university research, training, technology transfer and social dialogue, which will provide cross-disciplinary support within Quebec’s AI development strategy.
2. We must help Quebec as a whole contribute fully to this shift in the sectors that have build its historic strength and enable the Quebec education system as a whole to produce more AI and digital science specialists.
3. We must continue to support IVADO and SCALE.AI and build on their current momentum.

These three imperatives are centered around five major strategic directions on which this strategy rests:

- Maintain Quebec's academic leadership
- Develop talent
- Support technology transfer and marketing
- Develop a centre of expertise in responsible AI
- Develop robust support structures

This report presents these five strategic direction as well as the 12 detailed recommendations related to them. It should be noted that some of these recommendations could – and should – be implemented without delay, while others will require a more in-depth interaction between ecosystem stakeholders.

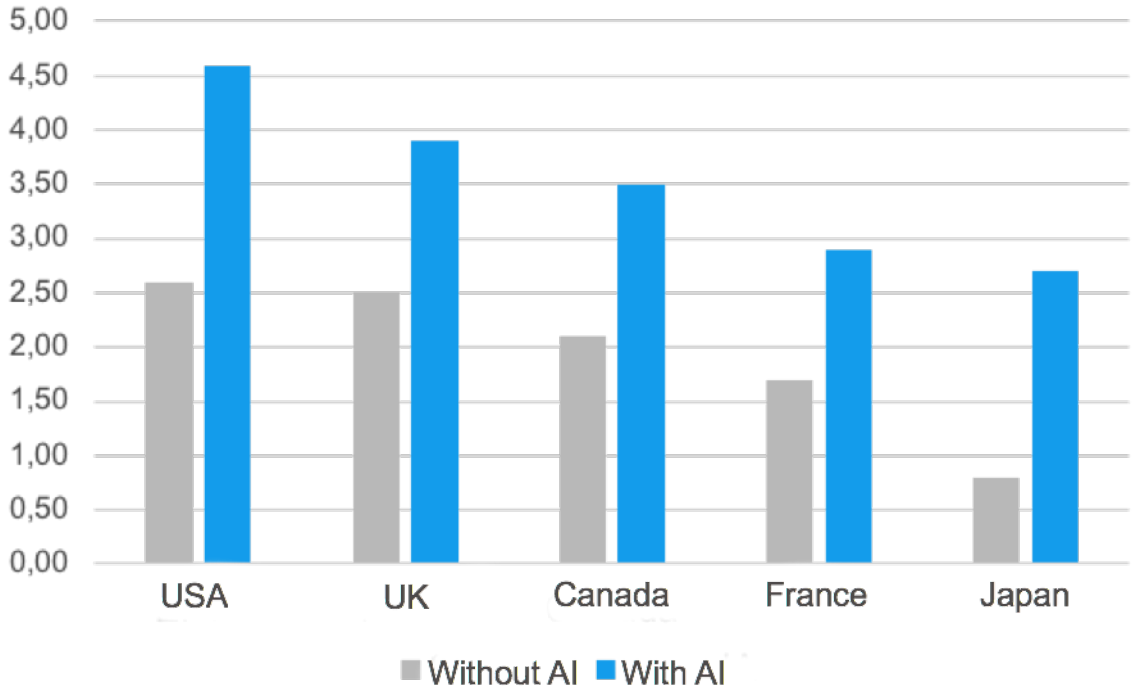
Steering Committee views

1. AI is a tremendous economic driver

In a recent study, McKinsey & Company estimates that the use of AI is expected to generate global productivity gains of 0.8-1.4% per year by 2065 (as a point of comparison, the invention of steam produced a 0.3% increase in productivity between 1850 and 1910).[7] These increases will ultimately increase the overall level of wealth in our societies.

Thanks to AI, the planet's countries will enjoy much higher economic growth in the future than they would have recorded without this technology (see chart below). As a result, by 2030, AI's contribution to the global economy is expected to reach US$15.7T, as if 10 countries the size of Canada appeared on the planet and injected it with wealth.[8] For example, the United Kingdom estimates that, on its own, AI has the potential to generate more than £600B in its economy by 2035.[9]

AI's impact on real gross added value growth (%)[10]



These major gains will mostly take the form of savings. That is to say, thanks to AI, it will cost less to:

- respond to citizens or customers (conversational agents, or chatbots, will be able to automatically process the most frequent written requests submitted to public authorities or companies).

[7] Voir https://www.mckinsey.com/global-themes/digital-disruption/harnessing-automation-for-a-future-that-works.
[8] Voir http://www.businessinsider.com/infographic-ai-effect-on-economy-2017-8.
[9] Voir https://newsroom.accenture.com/news/artificial-intelligence-poised-to-double-annual-economic-growth-rate-in-12-developed.
[10] Voir https://goo.gl/v1GWVM.

- prevent the emergence of serious diseases (a Montreal company, Imagia, has created software that can predict two years before any radiologist if a lung nodule is malignant). [11]
- transport goods from Montreal to Quebec (driverless trucks will be able to transport goods from one city to another).
- create new characters from scratch from existing images or photos in video game companies. [12]
- discover new ore deposits (a mining company used AI to predict the location of 86% of Abitibi's gold deposits by reviewing data for only 4% of the region). [13]
- manage a company's inventory (Amazon is currently testing robots that are able to prepare a package and replenish its warehouse shelves). [14]

These gains will also come in the form of innovations. AI will allow:

- learners to put their knowledge into action or take personalized courses (e.g., Duolingo gives Internet users the opportunity to practice their Spanish with a conversational robot and provides lessons tailored to their needs, strengths and weaknesses). [15]
- travelers to plan their trip (the mobile app of Quebec company Hopper lets Internet users know when they should buy their plane ticket to save money).
- researchers to make still unimagined discoveries (by automatically analyzing millions of scientific publications, IBM's tool Watson discovered in a few weeks almost all the kinases – key proteins in the human body – that the biologists across the world had taken nearly 15 years to identify, as well as totally unknown kinases).[16]
- older people to live longer, independently and comfortably at home because a robot can complete complex domestic tasks, such as cooking or cleaning, etc.

In some cases, companies using AI will even be able to create new business models that will revolutionize their industry.

In fact, according to researchers at the University of Toronto, AI fundamentally reduces the cost of making predictions, and "when making predictions becomes cheap, more predictions are made." Initially, the authors stress, the algorithms will be able to perform certain predictive tasks now entrusted to humans, thereby enabling organizations to save money. However, "a prediction machine may become so accurate and reliable that it changes how an organization does things. Some AIs will affect the economics of a business so dramatically that they will no longer be used to simply enhance productivity in executing against the strategy; they will change the strategy itself."[17]

In summary, AI is a major technology that Quebec companies will need to start integrating as quickly as possible to remain competitive at the provincial, Canadian and international levels. To this end, they will need the close support of many stakeholders, including those in research and technology transfer.

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[11] Voir http://ici.radio-canada.ca/nouvelles/special/2017/02/intelligence-artificielle/apprendre-creer-predire-cancer-go-science.html.
[12] Voir https://futurism.com/these-people-never-existed-they-were-made-by-an-ai/.
[13] Voir https://www.techemergence.com/ai-in-mining-mineral-exploration-autonomous-drills/.
[14] Voir https://www.nytimes.com/2017/09/10/technology/amazon-robots-workers.html.
[15] Voir http://bots.duolingo.com/.
[16] See http://ici.radio-canada.ca/nouvelles/special/2017/02/intelligence-artificielle/apprendre-creer-predire-cancer-go-science.html.
[17] Agrawal, A., J. Gans et A. Goldfarb (2018). *Prediction Machines – The Simple Economics of Artificial Intelligence,* Harvard Business Review Press.

2. The importance of having a common language

The concept of artificial intelligence emerged in 1950, with Alan Turing's eponymous test: Can a computer communicate convincingly enough to persuade a human being that it is human? Coined in 1955 to describe the first lecture on the subject at Dartmouth College, in general terms and from an application point of view, the term “artificial intelligence” is used to describe machines or programs capable of exhibiting behaviours commonly attributed to humans, such as learning, problem solving or natural language understanding.

Because it stimulates the imagination, arouses a variety of interests and has evolved through scientific progress, the term AI can create confusion. To avoid misunderstandings, measure out efforts, and above all, demystify artificial intelligence, we believe it is crucial to establish a common AI lexical field by first making a conceptual distinction between two levels artificial intelligence: “weak” artificial intelligence, which designates a machine or program capable of performing a specific, potentially very complex but very specialized task, such as playing Go efficiently, and “general” artificial intelligence, which refers to a machine or program that can learn a multitude of tasks and transfer knowledge from one problem to another, as a human would. To date, only “weak” artificial intelligence forms exist, even though they involve more and more complex tasks.

While different techniques – such as logic programming – have helped advance artificial intelligence since its beginnings in the middle of the twentieth century, much attention has now turned to machine learning, which offers the best-known way to advance artificial intelligence through algorithms that learn from data or experiences. Three categories of learning algorithms can be cited: supervised learning, which involves extrapolating rules from a set of well-defined examples; unsupervised learning, which involves finding underlying structures in a dataset; and reinforcement learning, which is about improving decision-making by repeating experiences multiple times.

Some of these methods involve models and algorithms that have existed for a long time, but whose scope has increased tenfold in recent years due to the exponential growth of computing power and data availability (Big Data). Moreover, significant breakthroughs in deep learning – a form of machine learning – have led to the AI shift we are experiencing due to the ability to solve new types of complex problems that were out of reach with traditional approaches, for example, the development of autonomous vehicles.

Breakthroughs in deep learning and other forms of machine learning are what is driving the current boom in AI and are what many people refer to as AI in a narrower sense. Machine learning, a field in which MILA is a well-known world leader, is garnering extraordinary investments. It is also the area that seems to have the best chance of eventually leading to a form of general artificial intelligence. We must maintain Quebec's leadership in this field and market this technology to create wealth.

Massive amounts of data are required to develop AI solutions and update algorithms. These data must be prepared, structured, transformed, analyzed and interpreted, expertise which falls under the purview of data science, a multidisciplinary field that more generally aims to extract knowledge from datasets. IVADO – the Institute for Data Validation – has world-class expertise in data science and is recognized for its operational research hub. Operational research aims to develop conceptual mathematical models to optimize decision-making that involves complex issues. There are synergies between this discipline and machine learning, as evidenced by the Canada Excellence Research Chair in Data Science for Real-Time Decision-Making research program, which is positioned at the crossroads of these disciplines, as well as by the fundamental scientific objective of IVADO’s Canada First program, which is to build on the synergies between operational research and machine learning.

Also, it should be noted that AI is part of a wider digital transformation on which it depends and whose components are closely connected, in particular the Internet of Things, digitization and automation of processes. All of these technologies position data not as a by-product but as an "asset," a new "raw material" that must be generated, exploited, analyzed and valued.

Finally, other technologies that are still at the research stage are poised to accelerate the growth of artificial intelligence. Quantum computers, for example, could drastically increase the computing power available for AI optimization problems and applications. Quebec has recognized expertise in this field, as shown by the $33.5M Canada First Research Grant awarded to the Université de Sherbrooke in 2015.

3. The need to make choices and focus our efforts

With the rise of the AI, Singapore has chosen to focus its attention on certain aspects of its economy. With the creation of AI Singapore, the country has announced its ambition to revolutionize three sectors by developing advanced AI technologies. These three sectors are health, finance and "smart city" technologies, which include urban mobility.

Moreover, with the creation of the Data Science Consortium (DSC), Singapore is attempting to capitalize on its existing strengths in advanced analytics and data sciences through academic and industry collaborations. Specifically, the goal of the SDC is to facilitate the adoption and marketing of more mature technologies in three additional sectors: sales, logistics and the manufacturing sector.

The Steering Committee is convinced Quebec must also acquire sectorial excellence if it wants to win the AI technology race. In other words, to ensure its leadership, Quebec must make choices and stick to them. This concentration of efforts is all the more critical in a context where talents are limited and public and private sector investments in Quebec cannot match those of other states, such as China, or technological giants such as Google and Amazon.

In its 2018-2019 budget, the Quebec government has tagged certain priority sectors such as education and health, in which more than $1.6B and $5.4B in additional investments are planned, respectively. The government is also planning major investments of more than $650M to protect the environment and promote energy transition, particularly in the mobility sector. These main priorities are complemented by other key sectors of the economy that the government plans to support, including clean technologies, biofood, life sciences and the financial sector. The development of supply chain projects is also one of the government's goals, as is the strengthening of Quebec's forestry sector. MILA, IVADO and SCALE.AI have also identified key areas of intervention: health, mobility, [18] logistics, [19] resources and green energy, as well as trade and finance.

Based on the priorities of MILA, IVADO and SCALE.AI, the Steering Committee concludes that the sectors that the Quebec's AI ecosystem will need to focus on over the next few years will most likely include health, energy, mobility, logistics and finance.

Note that the final choice of sectors to be favoured will be made in the implementation plan of the strategy defined in this document, after further consultation with ecosystem stakeholders. It should also be emphasized that the results achieved in the implementation of the business coaching programs referred to in Recommendation 7 may also affect future priorities. For example, mapping done in various

[18] Nous définissons la mobilité comme la capacité de déplacement ou la vue holistique du transport et du déplacement des personnes et de la marchandise, avec ou sans véhicule.
[19] Par « logistique », nous entendons l'ensemble des processus et des activités liés à la gestion des chaînes d'approvisionnement.

industries may show that AI techniques in which Quebec stakeholders specialize will have a greater impact in some sectors or niches than in others.[20]

It is important to emphasize that this positioning does not represent exclusion and is not a question of "choosing winners and losers." Rather, it is about focusing the efforts of government and ecosystem stakeholders in areas where Quebec can truly play a leadership role.

4. The need to elevate and make Quebec's ambition sustainable as well as to invest with conviction

The political will to make AI a driving force in the Canadian and Quebec economies is obvious. In addition to the significant investments already announced by both levels of government, a number of structuring initiatives – including the creation of SCALE.AI – have been launched.

However, the announced investments will not be enough to position Quebec as a leader. At most, these investments will only allow it to stay in the race. Moreover, the continuation of the initiatives launched by the governments in place depends largely on the electoral cycle. Therefore, while notable, these efforts are not enough.

Therefore, we believe that the government should sustain its efforts by making a much larger investment over 10 years instead of five. To generate the impact desired in Quebec, this investment must be $500M at minimum. We are aware that this is a big ask, but we believe that AI has the potential to become a real driver of the economy if we make the collective choice to invest in it.

The additional $300M added to the $202M committed to date would serve three purposes:

1) Sustain the anchoring institutes, MILA and IVADO, over a 10-year horizon.
2) Accelerate the development of AI and digital science talent within the ecosystem.

[20] Mentionnons, par exemple, que selon McKinsey, il y a plus d'avantages à utiliser les techniques « avancées » de l'IA (comme l'apprentissage profond) que des techniques de traitement de données plus traditionnelles dans des industries comme celles du voyage, du transport ou de la vente au détail. Voir à ce sujet https://goo.gl/8guv5W, p. 13.

Recommendations

Figure 2 — The interdependence of the ecosystem's components

While the strategic directions presented in this report can be understood and read independently, they constitute a whole within which each component is essential to ensure the growth and sustainability of Quebec's leadership in artificial intelligence.

Figure 2 shows the links between the AI ecosystem elements. The main issue is one which drives all the others: talent. At present, the supply of skilled labour in this area is failing to meet the ever-increasing demand. To provide leadership in AI research, design and use, Quebec must adopt measures to dramatically increase talent in this field. These individuals are researchers and students who are building the AI academic research and data science hub. They are young entrepreneurs who are actively involved in the design of AI applications and will contribute to the adoption and use of AI and AI-related fields in Quebec. When talent drives these three areas, marketing and technology transfer become possible. Training new talent boosts AI research, design and use and, through marketing, generates significant economic spin-offs for Quebec.

Some actions must be taken to strengthen Quebec’s AI ecosystem. Expanding the talent pool is, of course, closely linked to university research leadership, which largely determines our ability to train and attract new talent to the province's educational institutions. This leadership will foster the development of new national start-ups and technology transfer in the province. Therefore, this report’s first strategic direction proposes various recommendations, which run from how to attract renowned researchers to recruiting quality local and foreign students at the graduate level, to ensure the growth of an AI research hub.

The second strategic direction focuses on barriers that specifically limit AI and digital science development in Quebec, such as the lack of visibility of the ecosystem’s need for skills, the constraints of reviewing college and university programs, but also, the broader issues of mathematical literacy and the promotion of science.

For its part, the third strategic direction proposes measures to support the marketing process to accelerate the adoption and development of AI solutions across the Quebec economy. These measures will impact AI design organizations (i.e. start-ups) that have the potential to transform the province’s economic landscape as well as technology transfer and applied research centres. The measures will also impact user organizations (i.e. SMEs, large companies and government bodies).

The use of AI in our society not only generates a set of social, ethical and economic reflections including those regarding good governance essential to the technology’s acceptance, but it can also become a real asset for Quebec at the provincial, federal and international levels. The fourth strategic direction focuses on the development of a responsible AI hub in Quebec.

Finally, the fifth orientation aims to strengthen the ecosystem’s engine transversely and “add oil to its gears” by upgrading IT infrastructures and establishing a permanent organization to promote collaboration between stakeholders.

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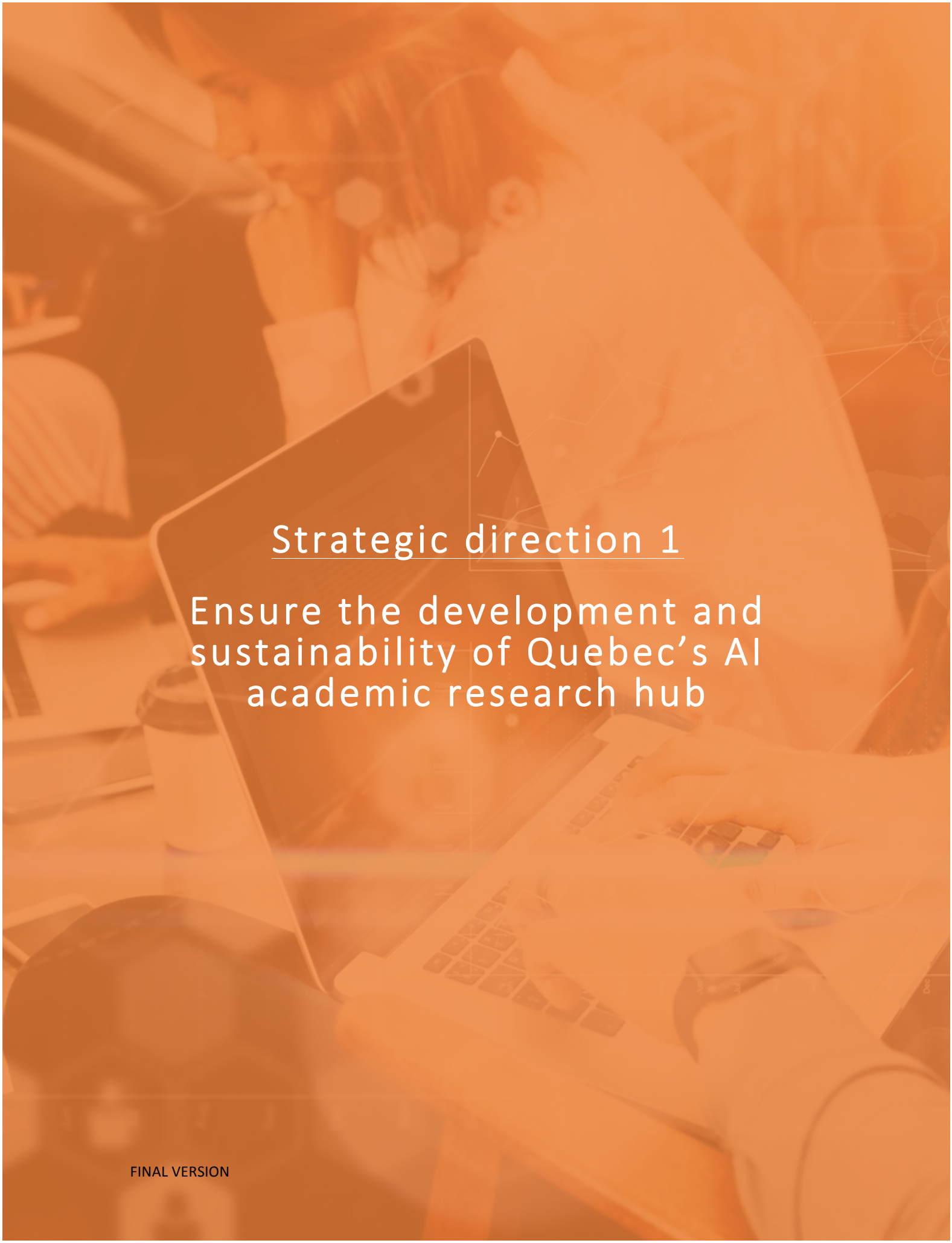


Strategic direction 1

Ensure the development and sustainability of Quebec's AI academic research hub

FINAL VERSION

> Recommendation 1: Increase our ability to attract researchers in areas where Quebec has the potential to become a world leader

FINDINGS

At present, Quebec is recognized worldwide for its expertise in artificial intelligence research. Indeed, it has the largest concentration of machine learning academics in the world – about 250 experts – and hosts one of the most well-regarded machine learning research centres, the MILA – Quebec Artificial Intelligence Institute. Moreover, several world-renowned scientists, including one of the three deep learning pioneers, Professor Yoshua Bengio, are based in Quebec.

In addition to this machine learning hub, Quebec is also recognized for its knowledge in AI applications research. For example, the McGill Centre for Intelligent Machines (CIM), created in 1985, brings together 21 researchers and 150 graduate students whose research in AI focuses on the use of algorithms in robotics, computer vision and person-system interaction.

Also worth mentioning, is the Institute of Data Valorization (IVADO), which brings together more than 1,000 scientists affiliated with the Université de Montréal, HEC Montréal and Polytechnique Montréal, who are developing cutting-edge expertise in the fields of data science, operational research and AI. Among IVADO's members are the Centre interuniversitaire de recherche sur les réseaux d'entreprise, la logistique et le transport (CIRRELT) and the Groupe d'études et de recherche en analyse des décisions (GERAD), two interuniversity research pillars in Quebec founded more than 30 years ago, which are home to the Canada Excellence Research Chair in Data Science for Real-Time Decision-Making.

Finally, we must mention the presence of the Centre de recherche en données massives de l'Université Laval (CRDM), which has more than 35 permanent members from five different faculties working on bioinformatics, unstructured data and the confidentiality, ethics and social acceptability of data use. The map of Quebec in Figure 3 shows the extent of Quebec's university network in AI and AI-related fields.

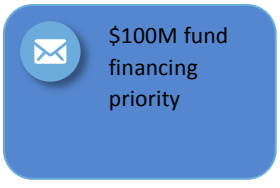
Quebec's academic research hub and historical advantage are fragile, however. On the one hand, there is a movement to democratize AI technology, especially with the rise of open source codes. Private companies, including Facebook, willingly share algorithms they've developed internally. On the other hand, many jurisdictions and large foreign companies invest heavily in AI and AI-related fields. These investments are used to attract researchers in particular. In 2016, investments by technology giants amounted to between $20B and $30B.[21] In 2017, Beijing announced its plan to increase the economic weight of the AI sector by $25B by 2020.[22] Quebec now has the opportunity to strengthen its academic research hub in AI and ensure its growth. Let's seize this opportunity and act quickly.

SUGGESTED APPROACH

Phase n° 1: Ensure the development of, and reinforce, a machine learning and deep learning hub

As a first step, we recommend that the MESI grant substantial funding to the MILA – Quebec Artificial Intelligence Institute to ensure the development of the machine learning and deep learning hub currently focused at this Institute.

The funding provided to the MILA will make it easier to attract and retain high-caliber researchers in machine learning, deep learning and reinforcement



[21] McKinsey Global Institute (2017). Artificial intelligence : The next digital frontier.
[22] Voir https://www.challenges.fr/high-tech/le-plan-de-la-chine-pour-devenir-leader-mondial-en-intelligence-artificielle_488717.

learning, through which AI will become a powerful driver of economic and social development for Quebec. More specifically, the amounts paid to MILA will be used to:

- develop young talents (scholarships for gifted students, updated AI training programs for Quebecers, mathematical literacy promotion and the democratization of science).
- create research partnerships that will allow the emergence of new AI companies and the adopted of AI by Quebec SMEs operating in key sectors of the province's economy.
- improve access to the computing power and computational expertise for researchers and some AI firms to make their work more efficient
- incubate businesses.

All these elements will help create a rich and stimulating ecosystem university researchers will appreciate. Highly qualified personnel will also be responsible for the supervision of applied projects and internships for students enrolled in professional master's programs and advanced graduate diploma programs, which will rapidly train more than 100 graduate students each year.

It should be noted that the MILA will ensure the close involvement of stakeholders from different Quebec educational and research institutions, both in its activities and the governance structure it will set up. For example, it is already planned that a representative from Université Laval will sit on the MILA Board of Directors. Similarly, discussions are underway to clarify how this Institute will collaborate with researchers outside Université de Montreal and McGill University.

Investing in MILA and in research to grow the economy is a sensible choice

The decision to make MILA one of the driving forces behind the growth of Quebec's AI sector and economic development is in line with that of other countries. For example, the U.K.'s new AI strategy aims to provide the Alan Turing Institute with resources that will allow it to expand rapidly, become a national AI research centre and collaborate with foreign centres. Germany is a major player in the sector with the Deutsche Forschungszentrum für Künstliche Intelligenz (DFKI), an organization in which some 900 researchers and graduate students, with state and industry support, participate in 300 research projects. The implementation of South Korea's AI plan is largely based on the creation of a national research centre as part of a public-private partnership. Recently, Japan has used a similar approach by investing $340M to found two new basic AI research centres.

Phase n° 2: Facilitate pan-Quebec mobilization to foster the development of AI applications research and its potential impact

We propose three steps to ensure the growth and durability of AI applications research excellence:

1) Quebec has strengths other than MILA in academic research. These strengths, which the province could build on to bolster its sectoral positioning, include researchers working on AI applications that will underpin the development of Quebec's main economic sectors. These strengths also include researchers from different disciplines who are assessing the impact of AI on individuals, organizations and societies, thinking about the social innovations needed for AI penetration to achieve expected results and concerned about responsible AI development.

2) **We therefore recommend that the Quebec government participate in the creation of 20 to 30 sectoral excellence chairs in AI applications in Quebec's top-priority sectors, such as health, mobility and logistics, as well as the social, societal and human aspects of the development and use of AI.**

While it is essential to ensure the development of basic research in the areas of advanced machine learning, it is also crucial to support research into the applications of AI within industrial and academic sectors that are Quebec's strength. The creation of these sectoral chairs will encourage the contribution of all Quebec researchers to the development of AI, based on the hubs already present in Quebec universities. It is important to distinguish the above-mentioned sectoral chairs from the MILA – Quebec Artificial Intelligence Institute's CIFAR chairs and to highlight their complementary nature. The CIFAR chairs ensure the growth of the fundamental research hub in machine learning, deep learning and reinforcement learning. The sectoral chairs will help develop AI application research in sectors in which Quebec has always been very strong. They will also intensify work on social, societal and human aspects of AI penetration. Moreover, it is expected that a portion of the CIFRA funds the MILA – Quebec Artificial Intelligence Institute receives will be redirected to third-party universities (e.g., Université Laval) to support the development of expertise in machine learning, deep learning and reinforcement learning throughout the province.

One of the three Fonds de recherche du Quebec (FRQ), the FRQ-NT (Nature et Technologies), the FRQ-S (Santé) or the FRQ-SC (Societé et Culture), could be responsible for the creation and management of sectoral chairs of excellence. The FRQ's three research funds could collaborate to make it possible to award chairs in various fields ranging from health to transport to the societal impact of AI. The designated fund will need to appoint a committee of experts to evaluate applications for the granting of the chairs.

The Government of Canada, through federal institutions such as the Canada Research Chairs Program, will also be asked to participate in the creation of the 20 to 30 AI chairs.

We do not recommend a specific process for granting the chairs. The designated fund will decide whether a quota of chairs will be allocated per university or whether all chairs will be accessible to all universities. Similarly, the fund will have to decide on the nature and duration of the chairs. Among the criteria for evaluating chair applications will be the ability to show how the research group will fit into the ecosystem and collaborate with current research laboratories. As an indication, seven-year chairs, with an annual value of about $250,000 each, would represent a total cost of approximately $35 to $52.5M, depending on the number of chairs awarded. There will also be additional costs involved in operating and implementing the appropriate infrastructure. The government could also consider partnering with private companies that could fund, at least in part, some of these sectoral chairs.

Chairs are an excellent tool and could even be described as necessary for attracting and retaining top researchers. Nevertheless, we must admit they are not always enough. There are additional barriers to researcher recruitment, some of which are structural ones within the academic community. Beyond the establishment of chairs, we must therefore make some related proposals to overcome these obstacles:

- First of all, let us consider the issue of job creation for recruited researchers. The process of creating a new position is not only complex – the approval of both the faculty and the department is required – but also extremely demanding for the university, given the long-term nature of the positions created. **We therefore recommend that the ministère de l'Éducation et de l'Enseignement supérieur support the faculties and departments involved in creating new positions that would result not only from the chairs awarded, but also from hires in AI-related streams, which will provide basic computer and mathematics education**, a type of education that will certainly increase in popularity by attracting more local and foreign AI students (see Recommendation 2).
- The retention of researchers becomes an issue when a chair expires. Universities find themselves in a delicate situation where they cannot afford to pay the equivalent salary to researchers. **We therefore recommend that the government put in place, over the long term, a chair program that will promote the emergence not only of AI, but of all the sectors and technologies of the new economy**. Over the decades, the themes of the chairs can change depending on the areas Quebec wishes to promote. This program will continue to support and retain the most promising researchers in Quebec.
- The issue of researcher retention is also crucial for holders of the MILA CIFAR chairs, which last five years and whose purpose is to finance the development of a research hub in machine learning, deep learning and reinforcement learning. To retain researchers as the CIFAR chairs are instituted, **we recommend that the Quebec government intercede with the federal government to ensure the renewal of the funding for these chairs or the growth and sustainability of the CIFAR basic AI research excellence chairs.**
- **Also, we invite the government to engage in a deep reflection regarding the systemic issue of compensation offered to university researchers, which often cannot compete with high-tech sectors.**
- Lastly, beyond the chairs and government support for the creation of new researcher positions, Quebec needs to be creative if it wants to attract highly talented researchers. For example, China (see the case study below) creates tailored recruitment packages in its Thousand Talents Plan and recent measures such as the creation of the AI City (salaries of $1M or more, grants for children's education, guaranteed employment for spouses). **We therefore recommend that a government earmark a budgetary envelope to support universities in recruiting world-class AI and AI-applications researchers.** Given that universities do not all have the same researcher recruiting issues, we suggest they submit their needs to the government, which will manage the awarding of grants.

2) In addition to supporting universities, **we recommend that the government support Quebec CEGEPs in their training and research capacity.** At present, many projects are underway in the college network. For example, the creation of an Attestation of Collegial Studies in AI and a Diploma of College Studies in AI at Collège Bois-de-Boulogne. To ensure the success of these programs, it will be necessary to recruit professors and researchers who have excellent knowledge of AI-related fields. However, it is difficult to attract faculty to these institutions, given the overwhelming demand for AI specialists across the ecosystem. If Quebec wants to attract excellent professor-researchers within the college network to not only educate, but also do research, it becomes imperative to support the CEGEPs in this process, for example, by creating a budgetary envelope that will be used to support the college network in its recruitment of professors in AI-related fields.

3) **Finally, we recommend applying to Employment and Social Development Canada and the ministère de l'Immigration, de la Diversité et de l'Inclusion du Quebec to enroll faculty and academic researchers in AI-related fields on the list of professions for the "Volet talents mondiaux" pilot project, launched in June 2017.** This addition would make it possible to process applications for a work permit in just 10 working days. Already, the list of these professions covers many areas of the information and communication technology sector. Since it is updated annually, it is imperative to act quickly to implement this recommendation. Between June and December 2017, 10-day processing was respected for 95% of the 850 applications. In addition to professors and researchers, the government should also take advantage of the updated "Volet talents mondiaux" list to include other AI-related professions, such as researchers visiting for a few months and AI trainees and programmers.

Attracting highly qualified researchers is of vital importance to the development of Quebec's AI academic research hub. Indeed, the growth of a critical mass of renowned AI and AI-applications researchers leading-edge sectors in Quebec will help increase the province's prestige in this field, which will in turn attract students and other researchers. Attracting highly talented researchers is therefore the key issue that will propel the virtuous circle of growth and sustainability of Quebec AI academic research leadership.

CASE STUDY

In 2008, China launched its Thousand Talents Plan, an initiative to repatriate, over a 10-year period, 2,000 Chinese "global experts" working internationally. These "global experts" are defined as PhDs who have attained the level of Assistant Professor at a recognized university or scientific institution. In 2011, the program expanded to include attracting foreign scientists to China. To date, this program has already exceeded its objectives, since more than 7,000 scientists have been repatriated.[23]

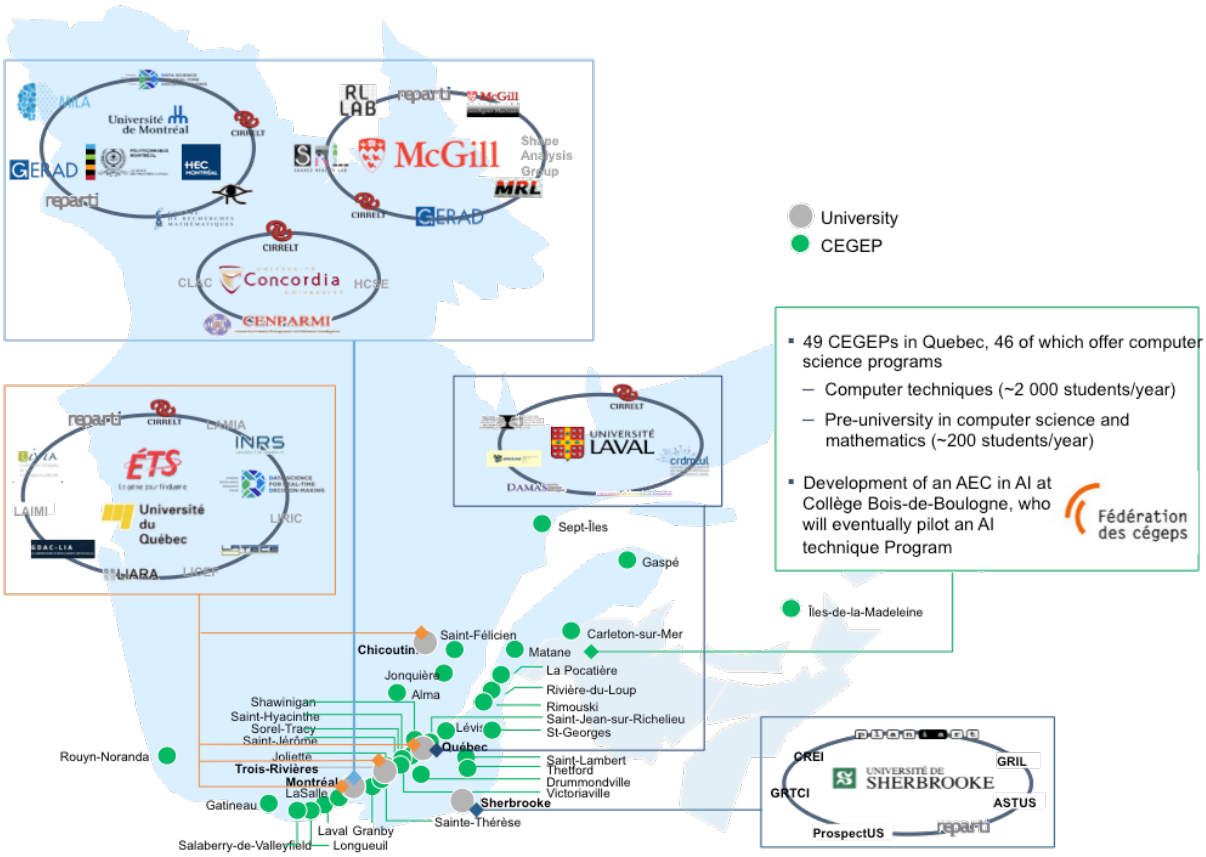
The Thousand Talents Plan provides Chinese universities with a reserve fund to attract highly qualified talent internationally. These funds are in addition to the funds already planned by universities to create researcher positions and make it possible for universities to offer competitive packages to world-class researchers.

Moreover, Chinese universities receive government grants for their international recruitment activities (travel, promotions, etc.). These grants are not a sub-component of the universities' budget, but an independent budgetary envelope, which encourages universities to expand their recruitment beyond China.

Finally, universities are invited to offer customized recruitment packages to the various scientists they wish to attract. Any salary surplus is negotiated, and, very often, other benefits are offered, such as a relocation allowance, subsidized education for children, paid return airfare to return to vacation in the country of origin, guaranteed employment for spouses, meal allowances, housing subsidies, etc. Some universities even allow recruited researchers to spend 50% of their time in their country of origin.[24]

[23] Voir https://www.nature.com/articles/d41586-018-00538-z.
[24] Conference Board of Canada (2016). The Thousand Talents Program – Lessons From China About Faculty Recruitment and Retention.

Figure 3 – Quebec universities, AI-related research centres and CEGEP network offering an IT program



> Recommendation 2: Ensure the inflow – in quantity and quality – of local and foreign graduate students in AI and AI-related fields

FINDINGS

Currently, universities are experiencing a slight increase in graduate student enrollment across all fields, especially at the master's level. On the other hand, it is more difficult, especially in areas such as data science and AI where profiles are highly sought after in the industry, to convince many students to engage in doctoral studies. The job market offers are attractive and rarely require a doctorate. In fact, the low value of a PhD in the Canadian labour market is the main reason given in an OECD report[25] for the lack of student interest in pursuing studies at the doctorate level. Yet, if Quebec wants to be a world leader in AI research, we need to attract more students and support them throughout their PhD studies.

[25] See https://www.oecd-ilibrary.org/docserver/5k92pghq4247-en.pdf?expires=1527308148&id=id&accname=guest&checksum=366E9D971EE22CE6576967EB89DDD5E3.

To fill positions in their research groups, researchers today turn to recruiting foreign students. In Quebec, in 2017, foreign students represented 20% of the student population at the graduate level and 40% of the students enrolled in doctoral programs.[26] Also, Quebec ranked last in Canada for the growth in the number of international students between 2000 and 2014. British Columbia, the Canadian leader on this front, experienced a growth rate five times higher than that of Quebec.[27] Currently, a foreign student's path from recruitment to integration in the workplace, is strewn with various obstacles that hinder immigration and permanent settlement in Quebec.

To start, tuition fees for international students are high, and international students do not have access to all the scholarships available to Canadian students, which can make finding funding more difficult.

Moreover, the figures show that in 2015, Quebec hosted about 43,000 foreign students at the post-secondary level, but only 3,500 selection certificates were issued to students.[28] According to Montréal International, the three main obstacles to retaining foreign students are access to employment (disparity in services offered within universities, reluctance of employers to hire students with a temporary status), the immigration process (unknown process that's considered complex, increased time for granting permanent residence) and the required level of proficiency in French (difficult to attain the language proficiency level required to obtain the Quebec selection certificate).[29] Yet today, Quebec is a destination of choice for many international students, according to the *QS Best Student Cities 2017* list, which ranks Montreal as the best student city in the world.[30] Moreover, according to the recent Nestpick study,[31] Montreal is the second largest city in the world for millennials. Considering that half of the international students would like to stay in Quebec after their studies[32] (according to a study conducted by Montréal International), we must conclude that a large number of them return to their home country after graduation, while we could have kept them here. It will be important to ensure that this does not happen in AI and AI-related fields.

The growth and durability of the Quebec AI hub should encourage many foreign students to immigrate to Quebec to pursue their studies. This is one more reason to ensure that their journey is smooth, from recruitment to integration into the workplace.

SUGGESTED APPROACH

We propose four measures to ensure the influx of local and foreign students to graduate studies in AI-related fields:

1) First, **we recommend making concerted efforts and ramping up current initiatives to promote science and technology and mathematical literacy, and to increase digital science and AI training from the high-school level to the university level.** Supplying and growing the pipeline of graduate students in AI-related fields begins with the democratization of science and the promotion of careers in the mathematical sciences from the grade-school level and also by growing the AI training offering. Recommendations 4 and 5 cover this topic in more detail, in particular by responding to the need to support educational institutions in updating their training offering and promoting science and technology to young people and women in particular.

[26] Ministère de l'Éducation et de l'Enseignement supérieur, Direction des indicateurs et des statistiques.
[27] Statistics Canada.
[28] See http://www.institutduquebec.ca/docs/default-source/recherche/8606_attirer-et-retenir-d-%C3%A9tudiants-intern_br_fr.pdf?sfvrsn=0.
[29] See http://www.montrealinternational.com/wp-content/uploads/2016/08/MI-Consultation-Immigration-2017-2019.pdf.
[30] Top Universities. *QS Best Student Cities 2017*.
[31] See https://www.nestpick.com/millennial-city-ranking-2018.
[32] See http://www.montrealinternational.com/wp-content/uploads/2016/08/MI-Consultation-Immigration-2017-2019.pdf.

See Recommendation 12

2) **In order to attract more local and foreign students, we suggest increasing the visibility and transparency of the research offer available to them.** For example, shared and centralized information would help students find professors to supervise them during their graduate studies. At present, many students who wish to do their graduate studies with Quebec professors recognized worldwide in artificial intelligence are denied their applications because of the limited availability of these researchers. A shared showcase would have the advantage of directing these students to other excellent researchers in AI-related fields in Quebec and, ultimately, to enrich the Quebec pool of highly qualified talent in AI and AI-applications research. Recommendation 12 of this report outlines the establishment of such a showcase in more detail.

3) If Quebec wants to attract more highly skilled local and foreign students who are doing research in AI-related fields and become a world leader in said fields, **we recommend increasing the funding available to students pursuing master's degree (master's degree in research, professional master's degree, diploma of higher specialized studies) and doctoral studies in these areas.** This initiative could include the creation of a bursary program accessible to the best local and foreign students studying in AI-related fields. Master's degree and diploma of higher specialized studies (DESS) students currently receive little funding, but these programs have the advantage of rapidly increasing the number of students enrolled, as students are not directly supervised by a researcher. The obstacle of insufficient researchers then becomes much less important. These programs also offer internships that helps foreign students develop roots in Quebec. Finally, bursaries offered to PhD students in AI-related fields should serve to encourage them not only to begin their studies, but also to complete them.

4) Finally, **to retain foreign students, we recommend upgrading current programs** such as those developed by Montréal International and Québec International as part of the strategy established by the ministère de l'Immigration, de la Diversité et de l'Inclusion du Quebec, which aims to increase the number of foreign students who settle permanently in Quebec at the end of their studies. For these programs, Montréal International and Québec International received grants of $1.6M and $0.2M, respectively, over three years. The enhancement of these programs could include the offer of free French courses for foreign students to facilitate and promote their integration and rooting in Quebec.

As we conclude this first strategic orientation, we must keep in mind that attracting highly qualified researchers in AI and its applications will further enhance the reputation of Montreal and Quebec as a whole and attract more local and foreign students. The aim is to create a virtuous circle where the ease of access to talented students will attract renowned researchers.

Strategic direction 2

Develop digital science talents to meet Quebec's needs

FINAL VERSION

Foreword

The previous strategic orientation addressed the need to ensure the growth and sustainability of the Quebec AI academic research hub. The rise of such a research hub is paramount since it will attract researchers and highly talented students. It will also drive the development of a talent pool in digital science to meet the needs of Quebec employers. Since most researchers and PhD and postdoctoral students teach, growth in the pool of students and faculty doing research will increase the number and relevance of AI-related courses offered at all levels (college, university, in-house corporate training and technology transfer stakeholders), thereby helping to train the skilled workforce that Quebec requires.

In addition, other measures must be put in place to match training to employment and support educational institutions in updating their training offer.

> Recommendation 3: Develop and maintain through a "talent watch" a clear and comprehensive perspective on needs, gaps and opportunities regarding digital science skills

FINDINGS

The areas of AI solution and application development are growing and require an increasingly abundant, qualified and diversified workforce. However, we currently have little knowledge of the exact size of this workforce, the specific needs of the industry in terms of job profiles and the number of talented people in the digital science Quebec institutions produce. A first approximation has made it possible to estimate that the talent gap is at least 1,000 graduates per year, a number that is potentially set to increase over the medium term. The need for talented people is obvious, but, currently, it is difficult to determine the exact number and precise skills required within businesses.

SUGGESTED APPROACH

$100M fund financing priority

We do not recommend training a specific number of students or creating a particular program; we are of the opinion that the exact magnitude and nature of the needs are too unknown to get specific about numbers.

Instead, we suggest getting a better understanding of the needs of talented people throughout the ecosystem so that they can mobilize and adapt quickly. This transparency of needs is critical to enable educational institutions to modify their training offerings accordingly, employers adapt their recruitment strategy and students interested in informatics or mathematics learn more about opportunities in these areas.

To improve this perception, we recommend setting up a "talent watch" that would have the following mandate:

1) Conduct a professional study to assess industry needs, current supply and training programs and identify future profiles and estimate the current and projected talent gap.

See Recommen-dation no 12

To ensure transparency about future profiles in areas related to AI, we suggest profiles be made accessible to students, thus promoting their interest in sectors where the need is greatest.

2) Provide a quick overview of the current offer of short "conversion" programs and continuing education programs; alert ecosystem stakeholders and the government if a shortfall is identified.

This second point is essential to rapidly increase the market's labour force without having to wait the three or four years required to train a cohort of undergraduate students. In other words, to ensure that new graduates in science, technology, engineering and mathematics (STEM) programs – who already have excellent mathematical literacy – can quickly convert and opt for a career related to AI and data science. This has been Singapore's approach with its AI Apprenticeship, a nine-month program that includes a six-month industry internship aimed at providing practical knowledge and AI work experience to recent graduates in computer science and mathematics. Students are paid between $2,000 and $3,000 a month for the full duration of the program. In its AI strategy, the U.K. has also outlined plans to study the potential for a one-year "conversion" master's degree for STEM graduates, so that they can apply AI to their respective specialties (e.g., biomedical sciences and AI). As these graduates already have the fundamental skills to work on AI applications, they could be quickly "converted" to work in the AI field.

See Recommendation 12

In addition, a review of all the AI and AI-related training programs available should be easily accessible to ecosystem stakeholders to help them to quickly find the program best adapted to their needs. This listing would include training programs at the college and university level but also the entire continuing education and online course offerings. On this last point, Quebec, as part of its *Plan d'action numérique en éducation et en enseignement supérieur*, has already expressed interest in setting up an "eCampus," an online platform that would list all the online courses offered by Quebec's post-secondary institutions and could potentially become a true online education collaborative campus. Moreover, the "talent watch" will need to tie in with current initiatives, particularly the eCampus project, and optimize its marketing to make Quebec education more visible internationally.

3) Perform competitive intelligence by observing what is being done internationally in terms of training offers and matching training to employment.

We recommend that this "talent watch" be placed under the responsibility of AI.Quebec (see Recommendation 11), supported by an existing organization (e.g., TECHNOCompétences) whose primary role will be to study needs. AI.Quebec will be supported by a committee of stakeholders from educational institutions and industry, who will provide support and advice, while rigorously validating the methodology, results and analysis. The presence of government leadership within the watch is essential to demonstrate the seriousness of the project and ensure active member participation.

Talent profile diversity in AI and AI-related fields

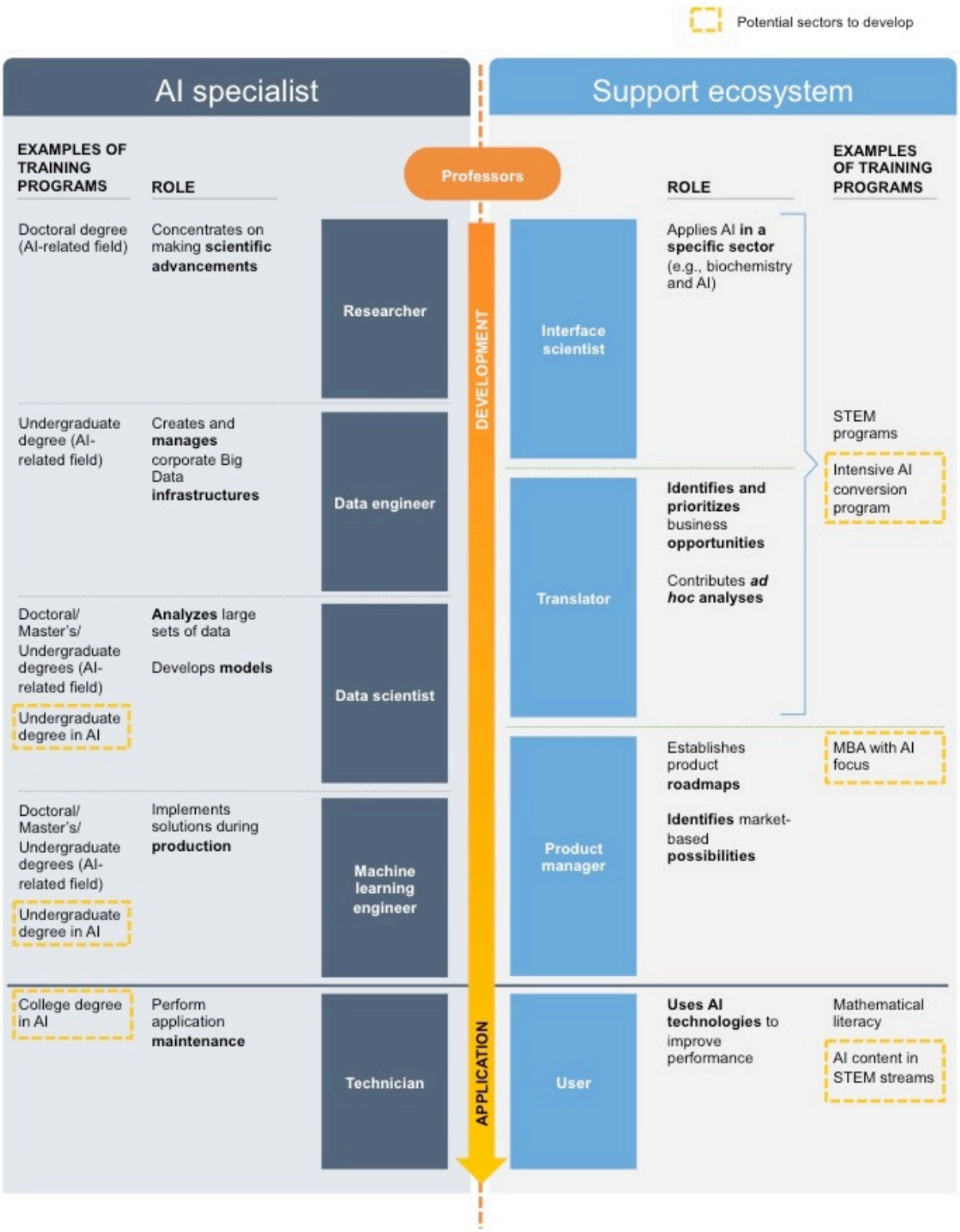
In this report, we make no recommendations as to the nature of the training to implement, but we have, through interviews with ecosystem stakeholders, identified various types of needs. Figure 4 gives a non-exhaustive view of the different profiles we identified during this first initiative; the objective here is to illustrate the diversity of profiles required to meet the growing needs of the artificial intelligence ecosystem, and more broadly, in the digital sciences.

Profiles fall into two broad categories: artificial intelligence and digital science specialists, that is, those who require technical knowledge in these areas (e.g., researchers, data scientists, machine-learning engineers) and "interface" stakeholders, who must have an understanding of the applications and transformation potential of artificial intelligence and advanced analytics (e.g., interface scientists, translators). All of these profiles can be spread over a spectrum that runs from R&D to the use and application of AI solutions.

In light of these efforts, it appears that some profiles will require the creation or modification of certain programs, such as the addition of an introductory AI course for MBA students, for example. On this last point, the French government, in its synthesis report on France and AI, has already taken steps to shift courses by announcing the introduction of AI modules in management schools to make future big decisions makers aware of AI issues.[33]

[33] See https://www.economie.gouv.fr/files/files/PDF/2017/Rapport_synthese_France_IA_.pdf.

Figure 4 – Illustration of the profile diversity required in the AI ecosystem



> Recommendation 4: Support educational institutions in updating their training offerings

Establishing a “talent watch” will be beneficial for all ecosystem stakeholders, including educational institutions, which can use it to review their programs accordingly. It is important to ensure a link and a transparent dialogue between the “talent watch” and educational institutions. At the same time, certain barriers prevent universities and CEGEPs from being flexible and agile in updating their training offer.

FINDINGS

Currently, Quebec's college and university institutions are struggling to obtain the financial resources they need to quickly update their training offerings to meet changing needs.[34] However, they have begun to revise some of their training programs to address the talent gap in AI-related areas. Université de Montréal, HEC Montréal, Polytechnique Montréal and McGill University, together with the MILA, are committed to creating new programs by offering a professional master's degree and a diploma of higher specialized studies in artificial intelligence in September 2018. The latter of the two programs runs for one year, including a four-month in-company internship. Université Laval will also offer a professional master's degree in AI by next fall. CEGEPs are also participating in this shift with the development of an Attestation of College Studies (ACS) diploma and a Diploma of College Studies (DCS) in AI at Collège Bois-de-Boulogne.

Quebec will benefit greatly from these programs, which will quickly train talent in digital sciences; however, they are not likely to meet the province's full demand for skilled labour, which is sorely needed. Educational institutions must act quickly to add introductory courses in the digital and AI fields to all of their science, technology, engineering and mathematics (STEM) programs and create online courses to support regional student training, to develop AI orientations or concentrations in current undergraduate programs and build new AI undergraduate programs. Moreover, CEGEPs must consider expanding their training offerings to meet the overall needs of Quebec. Finally, as mentioned in the previous recommendation, it is crucial to evaluate current continuing education programs and short conversion programs for new STEM graduates who could quickly acquire knowledge in data sciences and AI and enter the job market, all in less than a year.

To ensure the creation of a pool of AI talent, Quebec educational institutions must receive financial support from the Quebec government.

Also, the time required to create or update AI-related and all STEM programs currently ranges from two to three years, which means that it can five years from the beginning of the review to the first cohort entering the labour market.

SUGGESTED APPROACH

1) As a first step, **we recommend that financial support be provided to colleges and universities to support them in updating their training offering.** Given the exponential growth in the AI and digital industries' need for talent, it is important to ensure that the institutions that train this talent will have the means to do so. This support could take the form of a government budgetary envelope earmarked to support Quebec's educational institutions in updating their training offering. These institutions could submit their needs to the government, which would manage the awarding of grants. This government budgetary envelope must include a dedicated budget to

[34] Entrevues avec des acteurs de l’écosystème.

support online course creation, the benefits of which for Quebec are included in this document's Appendices.

2) **We also recommend simplifying and speeding up the government approval process for training programs offered by Quebec educational institutions** to ensure greater flexibility and agility in updating their training offering to meet changing needs.

   The government has already made commitments on this issue by redesigning the approval process for vocational and technical training programs for the Quebec college network. We also suggest that the university approval process be reviewed, as universities want and need to rapidly amend their training offerings to meet the growing need for a skilled AI labour force.

   To ensure that the training programs makes the best possible use of the Quebec university ecosystem, we suggest that this accelerated program approval process be applied first and foremost to programs submitted jointly by two universities or more. Interuniversity collaboration should be promoted to reduce redundancies, ensure baseline coordination between university programs and offer substantive training programs that make it possible for students to access the departments and expertise at several universities.

> Recommendation 5: Promote mathematical literacy and the democratization of science

FINDINGS

Currently, there is a significant global shortage of digital and mathematical science talent. However, a direct link exists between these skills and artificial intelligence: excellent knowledge of mathematical language is necessary to understand data science and AI basics. Therefore, feeding the pipeline in these two areas means feeding the pipeline in the mathematical sciences. To fill this talent pool, we must first and foremost make a Quebec-wide effort to democratize science and promote training and careers in science, technology, engineering and mathematics (STEM) to young people. This movement will reap benefits not only in the digital and AI fields, but also in all STEM training programs and future careers.

The under-representation of women is a notable issue in STEM streams that must be addressed. According to a report by TD Bank's Chief Economist, although women are better represented in the physical and life sciences, they account for only 20% of engineering graduates and 25% of computer science and mathematics graduates, despite the fact that these fields account for more than three-quarters of STEM jobs.[35] In deep learning, the proportion of women is even lower, at around 10%.[36]

Another finding: Today, in Quebec, about 21% of the population displays the lowest level of mathematical literacy, a level corresponding to the ability to perform simple mathematical operations usually involving a single step, and only one in 10 Quebecers have high mathematical literacy skills.[37] Given the rapid growth of AI and digital technologies, the workers of tomorrow will be called upon to use more and more AI-based digital tools. Therefore, it is essential to ensure that the entire Quebec workforce has a sufficiently high level of mathematical literacy to be able to accept and use these tools.

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[35] Caranci, B. (2017). Les femmes en STGM – Combler l'écart.
[36] Interview with ecosystem stakeholders.
[37] Desrosiers, H. et autres (2015). Les compétences en littératie, en numératie et en résolution de problèmes dans des environnements technologiques – Des clefs pour relever les défis du XXI^{e} siècle. Rapport québécois du Programme pour l'évaluation internationale des compétences des adultes (PEICA), Quebec, Institut de la statistique du Quebec.

With the support of stakeholders like the Governments of Quebec and Canada, many organizations and initiatives (e.g., the Boîte à science of the Capitale-Nationale and Chaudière-Appalaches regions, the Association pour l'enseignement de la science et de la technologie au Quebec, the Ambassadeurs scientifiques du Centre de développement de la relève scientifique et technologique project) are helping Quebecers, particularly young people, better appreciate and understand STEM, as well as promoting succession planning in this critical area for the future of AI. For example, in the coming years, the latest edition of the MESI's NovaScience program will make possible 36 projects aimed at enriching science and technology activities for vocational, college and undergraduate students, raising awareness among elementary, secondary and adult education students and developing professional practices among science and technology teachers in elementary, secondary and pre-university colleges. In 2016-2017, NovaScience launched more than two dozen awareness and training projects, three of which, conducted as partnerships, were specifically designed to increase interest in STEM in girls and women.

That being said, where STEM promotion is concerned, there is a clear need for collaboration, scaling up and sharing of best practices across Quebec

SUGGESTED APPROACH

The Governments of Quebec and Canada already support, through their actions and various programs, the development of a future workforce that can better understand and meet the challenges of STEM-related issues. As part of the 2017-2022 *Québec Research and Innovation Strategy – Daring to Innovate* (*Stratégie québécoise de la recherche et de l'innovation 2017 2022 – Oser innover*), the Quebec government has decided to strengthen the NovaScience program by injecting an additional $7.55M by 2021-2022.

Our recommendation is not to reinvent the wheel, but rather to better highlight and collaborate on the main initiatives undertaken in mathematical literacy and STEM-career promotion and increase their impact by ensuring optimal consultation between existing organizations.

We suggest that an ecosystem stakeholder be given the task of coordinating current science, technology and mathematical literacy promotion initiatives to increase firepower across Quebec. Quebec needs such an entity to leverage the appropriate means and meet the needs of those responsible for existing initiatives in terms of integration, consultation, evaluation, expansion and best practice sharing. Australia established such a body in 2002 with the Australian Mathematical Sciences Institute (see case study).

We stress that the support of such an entity in Quebec would have a positive impact on the AI and data science field as well as on all STEM-related fields in which Quebec has opportunity to excel, for example, video games and virtual reality, statistical biology, preventative medicine, finance, economics and engineering.

CASE STUDY

The Australian Mathematical Sciences Institute (AMSI) was created to strengthen collaboration and consultation regarding the promotion and democratization of mathematics and science within Australian society. The AMSI's mission is to dramatically improve the mathematical skills and competencies of Australians, including support for high-level mathematics education for young people, by growing the number of students in the field who are proficient in mathematical literacy at the post-secondary level, supporting research in the mathematical sciences and improving the experience of mathematics students at the university level.

AMSI operates on three fronts: research and higher education, school education and industry collaboration. Among the many programs developed by the Institute since its creation, Choose Maths is a national program that has received $22M in funding over five years from the BHP Billiton Foundation. Choose Maths aims to change the public's perception of women in math and science careers. To achieve this, the program plans to develop mathematics education in 120 Australian schools and add resources in all of these institutions, establish a national career promotion campaign in mathematical sciences, create a network of “inspiring women in mathematics” and hand out the BHP Billiton Foundation for Excellence in Teaching and Learning Mathematics annual awards.

Strategic direction 3

Accelerate the development and adoption of AI solutions within Quebec's economic fabric

FINAL VERSION

Foreword

Quebec currently has the opportunity to help create companies destined to make a mark in the AI sector. However, many barriers hinder the launch of such start-ups able to expand rapidly or successfully integrate AI into SME's more "conventional" IT products and services. For example, the current marketing ecosystem does not allow Quebec start-ups to effectively market their AI products to Quebec companies.

Similarly, many obstacles currently prevent many Quebec companies active in the primary, secondary and tertiary sectors from taking advantage of emerging AI innovations. For example, many companies do not fully understand the potential of AI on their activities and processes and have difficulty defining their own needs. The challenge is even greater for SMEs that do not have easy access to academic resources and consulting firms that can help them understand the power of AI and make logical technology choices.

Below, we outline three recommendations to facilitate both the marketing and adoption of AI applications across Quebec's industrial fabric.

See Recommendation 12

Lastly, as the ecosystem is complex and constantly evolving, it is difficult for companies to work within it and find suitable partners. Facilitating stakeholder networking between researchers, designers, users and business advisers is critical and will be covered in the fifth strategic orientation of this report.

> Recommendation 6: Support Quebec businesses that design AI solutions, including start-ups, so they can develop, grow and remain in Quebec

FINDINGS

In the current technological environment, the key to economic success is to ensure that new businesses take the place of businesses that will be phased out and that the "winners" enjoy conditions that promote their growth in Quebec.

Quebec must create and retain the economic value generated by new technologies to offset job losses associated with the productivity gains these technologies generate, while also attracting foreign investment.

The current ecosystem of AI application creators includes a number of promising start-ups that have secured funding locally and internationally. Quebec companies like Element^{AI} and Hopper raised $102M and $82M respectively in their last round of financing. Quebec's (and more specifically Montreal's) venture capital ecosystem is doing well. In 2017, Montreal businesses in all sectors raised ~$800M within the scope of 63 transactions, ahead of Toronto ($779M). Start-up funds and business incubators that favour AI start-ups are being set up. For example, the Quebec government has supported Creation Destruction Lab (CDL) and NextAI, two government-backed organizations, to the tune of $10M in its *2018 Economic Plan*. Montreal's Creation Destruction Lab wants to support nine cohorts of about 25 AI start-ups over the next three years. NextAI is a 225-hour training program that enables students, professionals and entrepreneurs to develop and implement AI-based ideas.

The funding gap during growth phases in Canada noted by the Advisory Council on Economic Growth seems to be closing. Initiatives such as the Venture Capital Catalyst Initiative (CCRI) and the Canadian

Business Growth Fund (BGF), with some of their funding which will be invested in Quebec, attempt to meet this need. Both of these funds are expected to contribute more than $1B nationally (over a five- to 10-year period). Also, investment funds dedicated to tech company growth capital are set to be announced shortly, including the Norda Capital fund.

However, there are still major challenges to overcome:

1) Access to data: AI application development requires massive amounts of good data. Today, the largest masses of data are held by large corporations and the government. And yet data is the most vital input – the raw material – of the emerging economy. AI companies' lack of access to these databases is a factor that limits the development of their business activities.
2) Access to computing infrastructures: AI application development requires considerable computing power. While Quebec has major computing infrastructures, such as Calcul Québec, they are mainly used for university research, and access to them is limited for start-ups (this issue will be discussed later under Recommendation 10).
3) Lack of AI talent: As is the case for other stakeholders in the ecosystem (universities, research centres, etc.), access to talent is currently a major challenge for start-ups. The added challenge for entrepreneurs is the need to find sales and marketing talent; these roles require both a basic knowledge of AI and a thorough knowledge of the potential client base.
4) Lack of a local market: Local start-ups must often seek international customers because of the lack of major "first customers" in Quebec, that is, anchoring organizations with the interest, means and maturity to work with local start-ups.

SUGGESTED APPROACH

Phase n^{o} 1: Ensure AI development companies have access to workable databases from the public and private sectors

Quebec's research centres, start-ups and SMEs will require large amounts of data to produce the AI tools that will help develop Quebec's economy.

The issue of AI data is decisive since application development in this field requires massive amounts of good data. As a Chinese financier pointed out, in AI "the more data you have, the better your product; the better your product, the more data you can collect; the more data you collect, the more you can attract talent; the more talent you can attract, the better your product will be. It's a virtuous cycle [...]."[38]

Unfortunately, this indispensable raw material is often very difficult to access. Few countries have large companies that, like Google, Amazon, Facebook or Baidu (the Chinese Google), have access to almost infinite amounts of data thanks to their hundreds of millions of customer-users. Start-ups and SMEs that are active in AI would benefit greatly from the openness of data collectively held by companies in sectors such as transportation or insurance. However, for fear of weakening their competitive advantage, these sectors are generally reluctant to share their data.

AI firms around the world also often have difficulty accessing data from national or sub-national governments, which are among the "richest" data sources. Sometimes government agencies would like to make public data available to companies, such as those in the AI sector, to develop products and services of benefit to society as a whole, but they cannot do so without adequately taking into account the rights

[38] See https://www.nytimes.com/2017/06/24/opinion/sunday/artificial-intelligence-economic-inequality.html.

and wishes of its citizens. The British public health authority and Google Deep Mind learned this lesson the hard way after sharing the records of 1.6 million patients without their knowledge.[39]

In the end, the relative scarcity of data available to Quebec's start-ups and SMEs could affect their international competitiveness and their ability to help develop Quebec's economy.

There are ways around this major hurdle, however. For example, countries like Great Britain (see case study below) have considered creating data trusts to ensure better dissemination and use of the data companies hold. In short, these countries plan to support:

- The pooling of data held by a particular set of organizations (e.g., companies and organizations active in a specific sector of activity such as health) on their activities, "customers" (whether these are citizens, patients or consumers) or other points.
- The management and circulation of these data under certain conditions (e.g., their prior anonymisation and exclusive use for new model training), which would not only be established by the participating organizations, but also by the people whose data is concerned (e.g., transit or taxi service user, hospital or clinic patient).

Trusts should have the resources necessary for the effective management and use of the data under their control, as well as the protection of the interests of all parties involved in the sharing of such data (e.g., health facilities, patients, researchers and AI companies).

CASE STUDY

In the British report *Growing the Artificial Intelligence Industry in the UK*, the issue of data accessibility is deemed important. The report's three recommendations on this point are:

– Develop data trusts, which are secure databanks, to facilitate the exchange of sensitive data while ensuring trust in the data sharing process.

– Produce more data from research activities that machines are able to process.

– Promote data mining in all industrial sectors to encourage companies to leverage data.

The data trusts, which consist of secure data sharing between multiple parties, has the greatest potential. At present, these sharing agreements are *ad hoc,* and organizations do not always know how to go about sharing sensitive data. The UK report therefore recommended that the government and companies form one entity, the Data Trust Support Organization, whose role would be to establish best practices for sharing data and provide all public and private organizations with a user manual guaranteeing a secure process (templates, secure data transfer process, etc.)

In their AI strategy, all countries want to make better use of the State as a significant asset to help businesses access the data they need to build successful applications. As mentioned above, Finland has made open data from Finnish ministries and agencies, and its use, a priority.

[39] See https://www.courrierinternational.com/article/royaume-uni-google-acces-aux-dossiers-medicaux-de-16-million-de-patients.

Currently, data collected by the Quebec government and Quebec municipalities is often very difficult to access. A 2016 CEFRIO study conducted by École nationale d'administration publique (ENAP) researchers shows that "despite the enthusiasm it has generated over the past few years at the international level, open data mostly remains an emerging phenomenon in Quebec."[40] At the time of the liaison and transfer centre's study, only 17% of municipalities had released data, compared with 60% of the Quebec government's ministries and 28% of its agencies.

However, these percentages conceal important facts. First, in the 12 months prior to the CEFRIO survey, none of the Quebec ministries had released more than five data sets and only 10% of the agencies had done so.[41] Second, among the government organizations that had not yet released data, very few were planning to do so within 12 months of the study. Moreover, many government computer systems do not allow for machine access or automatic access to ministry or agency data, and few of these data (less than 15% of the overall total) are automatically updated, two characteristics that make them less attractive and less useful for companies and researchers working in the AI sector.

According to the survey, Quebec government ministries and agencies cite the lack of good or relevant open data as the reason they have not yet released data. In some cases (especially in the ministries), the problem is the data is too sensitive. "We observe," say ENAP researchers, "that the assessment of the value and relevance of open data is not always as strong on the side of the original owner as the prospective user." [42] ».

According to the authors of the Quebec report, the release of government data is not yet a priority for all ministries, agencies and municipalities, a fact that is reflected in the lack of investments and efforts made in open data. Thus, in the 12 months preceding the survey, 58% of departments and 83% of organizations had invested less than $25,000 (excluding human resources costs) in the open data project. And, on average, the annual investments in open data for ministries and agencies were less than 50 person-days.

Therefore, data is the key input – the "raw material" – of the new economy that is emerging. Lack of access to quality databases for Quebec AI design companies could be a factor that limits the development of their commercial activities. The government will have a role to play in creating fertile ground for Ai companies.

The development of initiatives to remove some obstacles from the process, such as setting up a working committee which, under the coordination of the ministry of Finance, has looked at the general databank access process for research purposes. However, we will have to do more in the coming years to support the development of the AI sector.

Therefore, we suggest two major courses of action to significantly increase access to data for Quebec's AI stakeholders:

1) First, **we recommend that the government participate in the creation of a pool of anonymized data in specific sectors, such as health or transportation, in collaboration with large companies and other data holders, such as municipalities.** Access to these databases could be given to AI start-ups and ecosystem researchers, which would in turn benefit large companies and the government, as they will be able to improve their products and services through the applications developed (see the UK data trust case study above).

[40] See https://cefrio.qc.ca/media/uploader/RAPPORTNETGOUVDONNESOUVERTES-Final.pdf.

[41] *Ibid.*

[42] See https://cefrio.qc.ca/media/uploader/RAPPORTNETGOUVDONNESOUVERTES-Final.pdf.

The governance of these data trusts will be a priority issue to be addressed during the planning phase. It is imperative to question the sovereignty of our data and the responsibility of the Quebec government to make them accessible and deploy them to increase the collective well-being. Before implementing large-scale data trusts, it will be vital to study the ins and outs of the concept and validate their application in one or two industrial sectors. These tasks could be entrusted jointly to AI.Quebec and the observatory on responsible AI and the impacts of AI (see Recommendations 9 and 11).

2) **Then, we recommend that the Quebec government make the release of open data collected by all public and parapublic sector organizations a real priority for economic development.** In particular, the government should:

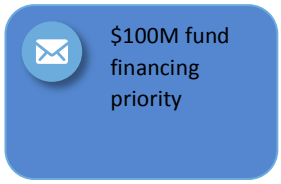
a) In the short term, for sharing and use purposes, reinforce Quebec's open data policies so that it applies to all its ministries. The model developed by the SOQUIJ (see the case study under Recommendation 8) could serve as a basis for this reinforcement work, since it reflects the realities of an organization that reports to a Quebec ministry and wishes to innovate through the use of AI.

b) Over the longer term, amend the *Act Respecting Access to Documents Held by Public Bodies and the Protection of Personal Information*, not only to promote the adoption of AI by the government, but also to give the ecosystem the opportunity to use anonymized open data in its own application development. Quebec has rich databases in the health sector. Addressing questions regarding their opening must be made a priority. Clearly, a rigorous but agile process needs to be implemented to avoid problems and potential leaks of sensitive information (see Strategic direction 4).

The government's dual role…

The government, as an important economic and social player in Quebec, must adopt best practices and act boldly to open up its data to promote their use for the benefit of all Quebecers, which will in turn drive the development of new applications by and for Quebec. This access to data does not in any way remove the Quebec government's responsibility regarding privacy protection. However, in addition to privacy considerations, the government is now responsible for rolling out and promoting data for the common good.

Phase n° 2: Develop a "first customer" market for ecosystem start-ups by subsidising Quebec business AI projects



To encourage Quebec companies to do business with start-ups that are developing AI solutions, we recommend the Quebec government earmark a budget envelope, in the spirit of Singapore's *SMEs Go Digital* program and the Finnish Government's Innovation Vouchers,[43] while respecting Quebec's trade agreements. This government assistance would help support companies that develop AI solutions, including start-ups, while promoting the digital shift to companies that are part of the more traditional sectors of Quebec's industrial fabric. For larger Quebec start-up projects with a price

[43] See https://www.businessfinland.fi/en/for-finnish-customers/services/funding/sme/innovation-voucher/.

tag over $500,000, project expenses may be eligible for R&D tax credits, which would create significant Incentive for companies that have a head office in Quebec and are of a minimum size (to be determined when the program is developed in detail). Such initiatives could also entice entrepreneurs to Quebec. Some tax credits are already available, like those that subsidize private partnership pre-competitive research or the integration of IT in SMEs.

A subsidy program to promote the shift to AI would evolve as follows:

- First, the government would allocate a budget envelope for this program that could be managed by an NPO that can facilitate networking (e.g., Prompt). This envelope could be used to improve on existing tax credits.
- Next, the NPO would act as a facilitator within the industrial network to help companies identify the best partners to meet their needs. For the sake of transparency, the list of all the AI companies that design solutions could be consulted on the government program website or the AI.Quebec platform. The NPO would also offer financial structuring services that meet the government tax credit criteria.
- AI customers looking to modernize or improve their products and services could contact these companies directly to assess their needs, knowing that some of the project costs would be covered by a tax credit.

At the federal level, we recommend that the Industrial Research Assistance Program (IRAP), managed by the National Research Council (NRC), be enhanced to increase the number of AI projects. Through this program, NRC promotes the development, adoption and adaptation of technologies within Canadian SMEs. IRAP has teams of Industrial Technology Advisors (ITAs) that assess the needs of SMEs. This SME consulting and diagnostic service branch should have close links with institutions such as the MILA – Quebec Artificial Intelligence Institute and IVADO.

Phase n° 3: Make it easier for innovative digital science and, especially, AI companies to access public contracts

Positioning the government or a public or parapublic sector company as a champion or a model user would have a catalytic effect on Quebec's AI ecosystem. To this end, **we believe it is important for the government to continue making strategic procurement improvements (as per Recommendation 6 of the CCEI), to make it easier for innovative service providers to access public contracts.**

Despite what is sometimes heard, it seems obvious that the current normative framework does not include a “lowest bidder” policy and that Quebec public bodies choose the adjudication method best suited to their needs. Moreover, in recent years, this framework has been enhanced to allow public organizations to use new approaches or tools in the digital domain (e.g., cloud computing, total net acquisition cost, competitive dialogue procedures) that offer increased procurement flexibility. The Quebec government has recently implemented measures that promote the development of technology companies and innovation integration in ministry and agency procurement processes (e.g., Passeport Innovation program, the Stratégie gouvernementale en technologie de l’information Government and the reverse technology showcase). The AI ecosystem and its future coordinating body will need to work in close collaboration with Quebec’s new public procurement support office, which Quebec government set up in accordance with the 2017 report of the Comité de travail sur l’entrepreneuriat des jeunes entreprises.

However, the Quebec government should continue to explore new avenues to help its ministries and agencies get the support they need to meet the often-complex challenges they face, and for which no single, ready-made solution exists, from start-ups and SMEs active in emerging digital sectors like AI. In

particular, the Quebec government should study the merits of adapting the U.S. Small Business Innovation Research (SBIR) program or the federal Innovative Solutions Canada initiative.

Innovative Solutions Canada is a $100 million program that aims to stimulate the expansion and growth of Canadian innovators and entrepreneurs by making the federal government the number one client for Canadian innovations. In total, 20 federal departments and agencies have set aside a portion of their budget to fund innovative solutions created by Canadian small businesses. This federal program should be actively promoted to innovative companies in Quebec as a gateway to the public sector.

Phase n^{o} 4: Support the development of AI start-ups by subsidizing certain marketing expenses, rather than R&D alone

Existing grant programs must include certain marketing-related expenses, which are excluded from the scientific research and experimental development tax credits (R&D) tax credits. For example, a portion of the salaries of key marketing personnel may be eligible. In an export context, some of these expenses are covered by government programs. For example, the Export Program, where the hiring of an export specialist or the cost of attending international trade fairs is eligible for financial assistance. These measures could be adopted within a broader market development framework. Therefore, **we recommend that the government revise its grant programs to include certain expenses related to marketing activities.**

In general, the government has a plethora of high-quality programs for innovative companies and businesses in all sectors looking to make a digital shift. These programs include the Audit Industrie 4.0 Audit for manufacturing companies, the PerforME strategy and the Passeport Innovation Program, which bring together several measures to help Quebec businesses. However, most companies do not seem aware of these programs, so they are not being leveraged to their full potential. To increase the visibility of all these programs, we suggest that they be listed on a common platform accessible to all businesses, such as Entreprises Quebec.[44]

CASE STUDY

In Singapore, the government has increased its SME digital project financing programs to support increasingly sophisticated needs, including AI. This type of program would be ideal for creating a "first customer" market for our AI design firms, while enabling traditional businesses to go digital.

The iSPRINT program, launched in 2010, aimed to encourage SME modernization by offering a grant of up to 70% of the cost of buying and implementing digital solutions pre-approved by the government, up to a maximum of $1M per SME. Start-ups or companies within the local ecosystem provide these solutions, thereby getting access to their first customers. This networking between private companies also reduces SME's dependence on technology transfer NPOs.

The new version of this program called "SMEs Go Digital" was launched in 2017 and helps these companies reach a more advanced level of digitization. The program now caters to companies beyond the first digital project stage. Pre-approved solutions now include advanced forms of advanced analytics, such as AI. This program has already enabled more

[44] See https://www2.gouv.qc.ca/entreprises/portail/quebec.

than 100 SMEs adopt digital solutions, which have generated more than US$2.4M for the program's pre-approved local suppliers. Moreover, to help companies navigate more complex digital notions, the government has set up a SME Digital Tech Hub to offer consulting and diagnostic services as well as SME Centres, points of contact for Singaporean SMEs. Finally, this new program prioritizes large-scale projects in key sectors of their industry as well as corporate collaboration.

IA and intellectual property

To develop the Quebec AI sector, the issue of intellectual property needs to be carefully considered. In the coming years, many start-ups and innovations will emerge from research conducted in university laboratories or colleges.

However, the transfer of intellectual property to the industrial sector presents significant challenges. The authors of the U.K. AI strategy note that spin-off is a practice some research institutions are better at than others (among other things, not all institutions have the capacity to work at the pace companies expect). They add that stakeholders experience other common problems. As a result, determining the return for each of the parties involved in a transfer agreement is usually a complex and contentious process.

Therefore, it will be important to ensure it becomes easier for existing entrepreneurs or businesses to make efficient and rapid use of the intellectual property developed by researchers and university and college students in Quebec.

New strategies and approaches could be developed to make the transfer rules for intellectual property held by universities and colleges more transparent and consistent. It might also be a good idea to create a centralized group of experts whose role would be to help research centres and companies in Quebec, particularly small ones, understand intellectual property issues and carry out transactions that would be of benefit to the various parties.

To improve Quebec's IP environment, ecosystem stakeholders will need to leverage the recent injection of $85.3M over five years announced by the Government of Canada in its Intellectual Property Strategy, "to help Canadian businesses, creators, entrepreneurs and innovators understand, protect and access intellectual property (IP) through a comprehensive IP Strategy."[45]

> Recommendation 7: Ensure future private sector AI users receive adequate support

FINDINGS

Contrary to what some people may think, getting the most out of AI is difficult, in the same way it's hard to take full advantage of IT.

As researchers at the University of Toronto have noted, "AI is a general-purpose technology. It has the potential to affect every decision, because prediction is a key input to decision making. Hence, no

[45] See https://www.ic.gc.ca/eic/site/108.nsf/eng/home.

manager is going to achieve large gains in productivity by just “throwing some AI” at a problem or into an existing process. Instead, AI is the type of technology that requires rethinking processes.”[46]

However, reviewing an organization's processes in depth requires expertise and the involvement of all staff members. “Data scientists can develop useful algorithms, but domain experts are needed to help train the machine to recognize important patterns and understand new data. Domain experts include top analysts, contract managers, salespeople, recruiters, and other specialists who are not only experts at their jobs but who are acutely aware of how they deliver excellence.” For AI to truly be a lever, says technology specialist Jeanne Ross, “it must improve on the skills of these specialists. Responsibilities must also be redefined so that they are empowered and motivated to roll out machines when they believe doing so will improve results. Ultimately, you need people who can use probabilistic output to guide actions that make your company more effective.”[47]

Many Quebec companies will require support to make this shift. Indeed, few of them (especially SMEs) currently have the knowledge needed to implement the technical and socio-organizational transformations on which to build an effective use of AI.

Direct and indirect support to companies that design AI solutions will be the first step to ensure the transfer of technologies developed in our research centres and leverage Quebec’s data. In addition to being new economic drivers in their own right, these start-ups will help local SMEs and large companies integrate AI into their processes and business models.

Other companies are also mobilizing to support potential AI users, with consulting firms increasingly involved in the AI sector to help their customers take ownership of the technology. Moreover, leaders of companies such as Thales Canada want to establish practice communities to promote peer learning and, on another level, develop common technology roadmaps through which to communicate needs to the local AI ecosystem.

Nevertheless, other technology transfer channels will have to be considered to ensure AI’s adoption throughout the local industrial sector. For example, IVADO, MILA and SCALE.AI will all participate in this technology transfer process with existing Quebec companies. Because AI is a new technology, few SMEs and large companies are adequately informed and equipped to undertake the AI shift.

A vast ecosystem of government-subsidized technology transfer agencies exists in Quebec to provide SMEs and large businesses with access to new technologies and support services. These organizations include, among others, the Centres collégiaux de transfert technologique (CCTT), the industry research clusters and the other members of the QuebecInnove platform. Today, these organizations do not necessarily have the expertise required to provide AI services to businesses and do not have the overall strength to respond to demand across Quebec. Indeed, a large part of the requests and questions related to AI coming from Quebec businesses are sent to research institutes (e.g., IVADO or MILA), which are not able to answer them fully.

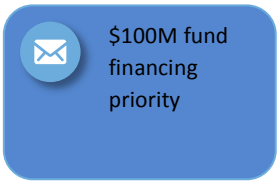
Quebec's model of applied research centres and innovation valuing is largely decentralized. Across the province, there are intermediate technology transfer organizations, but no industry sector has a critical mass of researchers and engineers dedicated to applied research. For example, the TransTech network, which includes all college technology transfer centres, employs 1,300 experts in nearly 50 centres. While many organizations now play a role in the transfer of cross-sectoral technologies such as digital technologies, the form a subset of these stakeholders might take in the future must be considered.

[46] See Agrawal, A. et al., *op. cit.*
[47] See https://sloanreview.mit.edu/article/the-fundamental-flaw-in-ai-implementation/.

SUGGESTED APPROACH

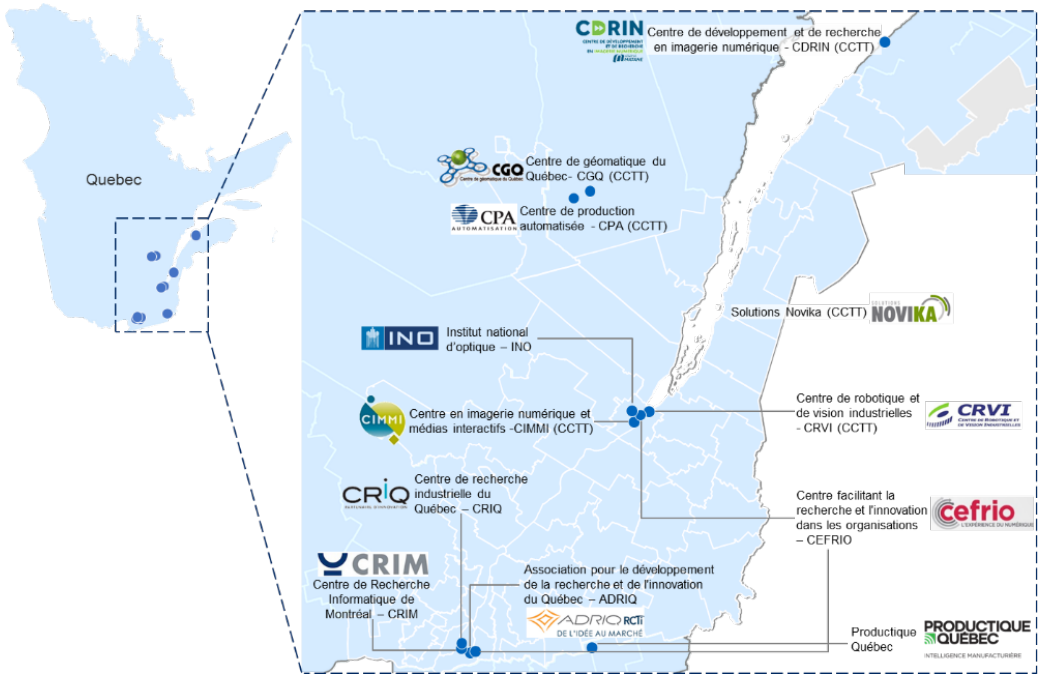
We see two potential fields of action to improve Québec's technology transfer infrastructure: a series of actions to be rolled out quickly, and another to be implemented over the next two years.

Phase n° 1: Upgrade the AI knowledge of Quebec ecosystem liaison and transfer stakeholders in the short term



1) **First, we recommend upgrading the AI knowledge and skills of a small group of support players who already provide consulting services to businesses and are ideally positioned as a "gateway" for them.** To this end, about 10 "champion" organizations should be chosen, from the roughly 70 existing organizations, to dedicate part of their resources to AI and data science technology transfer. Academic institutions (i.e. MILA, IVADO and universities) would provide training using a train-the-trainer approach. Following the ecosystem benchmark analysis, a dozen organizations appear as natural candidates: the following centres collégiaux de transfert de technologie (CCTT): Novika Solutions, the Centre de robotique et de vision industrielles (CRVI), the Centre de développement et de recherche en imagerie numérique (CDRIN), the Centre en imagerie numérique et médias interactifs (CIMMI), the Centre de géomatique du Quebec (CGQ) and the Centre de production automatisée (CPA), as well as the Centre facilitant la recherche et l'innovation dans les organisations (CEFRIO), the Centre de recherche informatique de Montréal (CRIM), the Association pour le développement de la recherche et de l'innovation du Quebec (ADRIQ), the Centre de recherche industrielle du Quebec (CRIQ), Productique Quebec and the National Optics Institute (INO). These organizations are mentioned in Figure 5.
2) **Also, it is important the government support these intermediary organizations in developing consulting teams able to assess a company's maturity or readiness to adopt AI and AI-related applications by identifying the most promising use cases and helping these companies find the best partners for their needs within the ecosystem.** In this context, a communication channel between these organizations and educational institutions is needed to ensure proximity to the latest technological developments. The QuebecInnove platform and the Audit Industrie 4.0 initiative could serve as a link between the various organizations.

Figure 5 – Geographical distribution of technology transfer organizations naturally positioned to receive AI training



Phase n° 2: Create a major support program to enable hundreds of companies to execute an AI project

Several technology transfer stakeholders operate in specific sectors and have a special relationship with the industrial clusters and the network of companies that make them up. Once the AI knowledge of their staff is upgraded, these stakeholders can participate in the implementation of programs to support these clusters and organizations in their AI shift.

To help SMEs make the AI shift, we recommend creating an important coaching program that will allow several hundred companies execute an AI project, with the support of liaison and transfer agencies and representatives of Quebec's main industrial clusters.[48]

The AI coaching program could be modelled on past government programs, such as PME 2.0, which various partners piloted in the 2010s to help businesses in Quebec's aerospace, fashion and retail industries leverage the potential of information and communication technologies.[49]

$100M fund financing priority

[48] The AI shift is contributing to data enhancement in businesses and is a logical extension of the programs already started under the *Plan d'action en économie numérique* et de la *Stratégie québécoise de la recherche et de l'innovation*. Companies with high digital maturity can use AI to leverage their data and improve their productivity and competitiveness. For example, companies that have participated in existing digital shift government programs may ultimately benefit from the programs recommended in this report to make the AI shift.

[49] From 2012 to 2015, the MESI mandated CEFRIO to implement the PME 2.0 program and help 30 aerospace and fashion and clothing SMEs affect a digital shift. These companies received support from industry partners, academic researchers and technology experts, and have invested close to $10M of their own to diagnose their level of digital advancement, plan their digital strategy, implement technology adoption projects, such as ERP (Enterprise Resource Planning) packages, and ensure the acceptance and effective ownership by their staff of the tools implemented. CEFRIO and its partners (e.g., Aéro Montréal) then widely disseminated the knowledge gained from these 30 experiments through the www.pmenumerique.ca portal and other transfer activities. The popularity of this program prompted the MESI to support a second edition of PME 2.0, which will end in 2018. This new phase aims to support the digital shift of retail and manufacturing companies as well as social economy organizations.. For more information, see https://cefrio.qc.ca/projets-recherches-enquetes/numerique-entreprise/pme-20/.

Initially, calls for applications open to all organizations involved in technology transfer and knowledge transfer on the use of technologies would be launched to select "champions" to support companies through this program. Under this initiative, government funds would then be used to:

- assess Quebec's main industrial clusters to determine how companies active in the province could use AI to create new business models, launch innovative products or services or increase their productivity, thereby becoming more competitive.
- determine which industrial clusters require priority intervention, particularly in view of AI's potential for each sector.
- provide customized support to some of the companies in these clusters (i.e. 10 to 15 SMEs in each cluster able and willing to undertake an AI project and invest some of their resources) so that they can integrate the AI effectively.
- codify the knowledge and know-how developed by the above SMEs and transfer them, to all the companies in the selected clusters.

This coaching program could also include a phase to help existing companies within the information technology cluster (such as, SMEs that are members of the Association québécoise des technologies (AQT)) acquire advanced AI technical knowledge with a view to improving their current product or service offering, by injecting more intelligence into customer relationship management (CRM) software, a document management tool or an inventory management system, for example.

A coaching program that complements other government actions

The coaching program outlined above fits in perfectly with one of the Stratégie numérique du Quebec's objectives, which is "to make digitalization an engine for business growth and a powerful lever for industrial development, especially through major investments in Industry 4.0 and the reinforcement of ecosystems that facilitate profitable interactions between the digital sector's supply and demand from other economic sectors." The Quebec government's 2018 Economic Plan embodies this objective in a number of ways. Over the next two years, the government will invest $60M to launch a call for proposals so that companies in various industrial sectors can bid on major projects to market new products, processes and services, address common challenges and test new business models. Even if it does not focus on the use of specific solutions, this new program will be beneficial to Quebec SMEs looking to use AI to solve the problems they are facing.

Moreover, the AI coaching program would complement existing or future Quebec SME programs, such as the Actions concertées des Fonds de recherche du Quebec, the MITACS programs, Investissement Québec's new program, which aims to help secondary sector companies follow through with applied training projects based on the "industry studies" model and the CRIQ stimulus programs designed to help manufacturing companies transform into 4.0 companies.

Phase n° 3: Consolidate several technology transfer organizations into a fundamental and applied research institute with strong industry roots

The overall goal is to re-establish the relationship between companies and applied research centres by drawing on internationally proven models, such as those of the Fraunhofer and IMEC institutes in

Germany and Belgium (see case study below). In concrete terms, it would be necessary to consolidate several existing organizations and align the efforts of the digital science ecosystem with those of Quebec clusters and existing sectoral tables. This consolidation should focus on applied research and technology transfer activities. **To this end, we recommend that the Quebec government begin thinking about process and additional funding needed to complete the restructuring of the relationship between businesses and applied research centres.** This recommendation is directly related to the CCEI's Recommendation 11.

CASE STUDY

Located in Leuven, Belgium, the Institut de microélectronique et composants (IMEC) is a research institute specializing in microelectronics. Its highly qualified staff includes more than 3,500 people (including researchers as well as project engineers). Due to its popularity with companies that are looking to carry out basic and applied research projects, IMEC is 80% self-financing. Its main activities are divided into two branches:

R&D solutions:

- Collaborative pre-competitive research projects with multiple stakeholders
- Bilateral research projects between a company and the IMEC
- Government-funded research

Innovation services:

- From idea to conception, the IMEC offers numerous innovation vehicles ("Living Labs," start-up incubation and acceleration programs, etc.).
- Prototyping and testing services for more advanced projects
- Production capacity and advice about growth

The IMEC's proximity to industry, critical mass of researchers and innovation services makes it a model research centre that strongly contributes to the market of the technologies developed within it, as evidenced by the 60 or so start-ups that have sprung from the IMEC since its inception.

In short, over time, the IMEC has become more than a research centre. Now it is a true innovation hub. The IMEC's 24,400-square-meter space includes accelerators, incubators and training rooms and holds numerous annual conferences and technology round tables.

> Recommendation 8: Position government and Crown corporations as model users that benefit from AI technology

FINDINGS

Given the large amount of structured data its various ministries generate (especially in the health sector), the government is the perfect potential customer for AI applications. Undoubtedly, the Quebec government is the leader in central information management systems in the public sector.

However, the government must overcome some obstacles to benefit from AI solutions. In addition to issues similar to those of large non-technology companies, such as access to talent and the need for greater awareness, structural issues need to be resolved if the government wants to position itself as a legitimate user of AI solutions. CEFRIO, in its *NetGouv* report on open data, sees only slight progress in the evolution of open government in Quebec. Indeed, fewer than 5% of ministries released more than 10 datasets in 2016. Since then, the situation has improved somewhat, but the issue persists. Keep in mind that public data accessibility and sharing is an essential condition for AI use in ministries.

CASE STUDY

The SOQUIJ has established a data management policy within the context of the development of AI-based legal information solutions. This policy respects the current legal framework and proposes security measures in line with industry best practices (including encryption and secure data hosting). The policy also evokes the notion of benefit and risk analysis regarding data communication and use and defines mitigation measures for identified risks. When the benefits of using data in an AI context are significantly greater than the risks, use is permitted. Internal and external ethical committees evaluate the recommendations when risk levels are high. Such a model could be used across ministries.

SUGGESTED APPROACH

We propose to position the Quebec government as an AI user through various impactful actions, including:

1) **Clear positioning in the Stratégie de gouvernement numérique regarding the adoption of AI solutions within the government apparatus.** This strategy should lead to the development of internal expertise, starting with teams in the Chief Information Officer's department within the Treasury Board (Conseil du trésor). This department would then coordinate an assessment in the five to 10 ministries or government agencies that possess the largest amount of data to identify common use cases of benefit to the government and citizens (e.g., tax evasion prevention at Revenu Quebec). After this assessment, the government will need to set clear goals on a number of priority issues.
2) **The modernization of the regulations governing the use of public data** (see also Phase 1 under Recommendation 6).

Implementing a government AI strategy

From a more tactical perspective, the operationalization of a government AI strategy could involve setting up an AI and data science squad able to support multiple ministries. Upgrading the skills of key staff already in place could be done through training offered by the various AI educational institutions, notably Université Laval's Centre de recherche en données massives because of its geographic proximity to the Treasury Board team, which includes the Chief Information Officer.

Strong and experienced leadership is also crucial for the technological shift. In 2014, the Obama administration had a team of former Silicon Valley executives, including some from Google, lead the government's most innovative projects. It would be an excellent idea for the provincial government to follow this example and attract leaders who have experience in major technology projects. On the data side, we recommend an AI-solution development data management policy be adopted. In this respect, the work done by SOQUIJ could serve as a jumping off point (see the SOQUIJ case study).

Strategic direction 4

Develop an international responsible AI and AI impact analysis hub in Quebec

FINAL VERSION

> Recommendation 9: Ensure the sustainability of ongoing responsible AI mobilization efforts and prepare to integrate emerging consensuses into Quebec public policy

FINDINGS

As we mentioned at the beginning of this report, the development of AI technologies and their implementation should have positive effects on society overall. That said, there is no doubt that AI's increasing prevalence could also have adverse effects, intentional or not, if not well monitored.

No doubt, some people, businesses and governments may be using AI tools – and, as Facebook and Cambridge Analytica have showns, the data they need to create them[50] – for illegal or morally reprehensible purposes. Some technologies, such as facial recognition tools, could be used to monitor consumers or citizens and surreptitiously gather information about their sexual or political preferences.[51] Other technologies may be used to deceive the public, as automatic image generators can create ever more convincing false news.[52]

In other cases, organizations will use AI to achieve their goals legally, but will have a negative impact on society as a whole. For example, a recent Wall Street Journal survey showed that YouTube tends to show extreme and catchy videos to internet users looking for "mainstream" videos to maximize its advertising revenue. Therefore, conspiracy, anti-vaccine propaganda or ultra-marathon videos may appear as suggestions to people looking for information about the U.S. President's State of the Union address, the flu vaccine or jogging.[53]

Using AI technologies could also have unwanted side effects, because they may codify harmful actions, such as discriminatory practices. For example, some of the algorithms used in the American legal system show that people who have had early contact with the police are more likely than others to commit a crime after being released on parole. This type of finding, however, results in the unjustified extension of the incarceration of many African Americans, since African-American teens are more often bothered by the police for no good reason than are white teenagers.[54]

AI applications will also have a significant impact on the Quebec and global economies. Indeed, there is no doubt that the rise of AI will result in the elimination or transformation of a significant portion of the jobs offered in many industry sectors. Automated text analysis and generation tools, autonomous vehicles or high-performance chatbots should have a positive overall effect on the productivity of businesses and

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[50] See https://www.nytimes.com/2018/03/19/technology/facebook-cambridge-analytica-explained.html?action=click&module=Intentional&pgtype=Article.

[51] See https://www.theguardian.com/technology/2017/sep/07/new-artificial-intelligence-can-tell-whether-youre-gay-or-straight-from-a-photograph.

[52] See http://www.lefigaro.fr/international/2016/10/04/01003-20161004ARTFIG00094-etats-unis-le-pentagone-a-debourse-des-millions-de-dollars-pour-de-fausses-videos-djihadistes.php.

[53] See https://www.wsj.com/articles/how-youtube-drives-viewers-to-the-internets-darkest-corners-1518020478. This phenomenon does not hold, stresses a columnist of the New York Times, that Facebook's engineers have the "desire to lead the world to ruin". It is more plausible, according to her, that this result has to do with the business model of Google, the owner of YouTube. "YouTube's algorithm seems to have concluded that people are attracted to more extreme content than they were looking for at the beginning of their research - or by generally inflammatory content. "
Ce phénomène ne tient pas, souligne une chroniqueuse du *New York Times*, au fait que les ingénieurs de Facebook ont la « volonté de mener le monde à sa perte ». Il est plus plausible, selon elle, que ce résultat ait à voir avec le modèle d'affaires de Google, le propriétaire de YouTube. « L'algorithme de YouTube semble avoir conclu que les gens sont attirés par des contenus plus extrêmes que ceux qu'ils ont cherchés au début de leurs recherches – ou par des contenus généralement incendiaires. »

[54] See O'Neil, C. (2017). *Weapons of math destruction – How big data increases inequality and threatens democracy,* Broadway Books.

workers but could quickly put many professionals, workers and technicians out of work or force them to acquire new skills to remain employable or maintain their income level.

AI's impact on the environment

In 2016, the electricity consumption of the world's data centres exceeded that of all the inhabitants and companies of Great Britain.[55] The rise of AI could cause a major increase in electricity consumption, because AI requires enormous amonths of data and computational power. Becoming a leader in responsible AI means that Quebec should also seek to minimize the environmental footprint of its activities in this area.

In response to these challenges, many of the countries that have adopted AI development strategies have also begun to reflect on the ethical, social and human issues associated with the development and use of AI.

For example, in 2017, the State Council of France commissioned a study entitled *Puissance publique et plateformes numériques: accompagner l'ubérisation*, which focuses specifically on the effects of AI on French society and the economy. In the United States, the *Future of Artificial Intelligence Act of 2017* addresses the importance of developing AI while protecting the privacy rights of citizens and creating unbiased tools. Moving from declaration of intent to operationalization, actors like AI Now in the United States, or the Future of Humanity Institute in Britain, began designing frameworks and methodologies that businesses and governments could adopt to frame the development of AI tools and their use.

Many elements demonstrate Quebec's unique positioning with respect to the social, ethical and legislative issues of AI and data science more generally.

In the field of machine learning, there is a broad consensus in Quebec within research teams regarding the need to develop a strong discourse to support the ethical development of AI. Several researchers in the field have been personally involved in this initiative, and organizations such as IVADO and MILA are closely involved in advocacy and knowledge mobilization activities about responsible data use and AI. Moreover, Quebec has strong research expertise in the legal sector (both ommon law and civil law), public policy and ethics, and researchers active in the province have mobilized around ethical and legal AI issues. Finally, the democratic tradition and respect for the fundamental rights in Quebec makes it fertile ground for developing a useful dialogue with citizens regarding AI issues and AI's social impact.

In this spirit, the Université de Montréal and the Fonds de la recherche du Québec organized the "Forum AI responsable" in 2017, in partnership with MILA, IVADO, the Canadian Institute for Advanced Research and the Palais des congrès de Montréal.

The Forum and the citizen participation process will conclude in December 2018 with the publication of the *Montreal Declaration for a Responsible Development of Artificial Intelligence*. The recommendations made in this document come both from a committee of scientific experts and the public consultation process. The implementation of the *Declaration*'s recommendations will help benchmark AI's future development so that it is done in a manner consistent with the values of Quebec society and allows not only for economic progress, but also for social progress.

[55] See http://www.independent.co.uk/environment/global-warming-data-centres-to-consume-three-times-as-much-energy-in-next-decade-experts-warn-a6830086.html.

Given the rapidly evolving nature of technologies and the social changes they bring about, it is essential to anticipate that these recommendations will need to be revised regularly. Indeed, it will be necessary to ensure that they continue to be improved based on the two pillars of the *Declaration*, namely the contribution of experts and ongoing public consultation.

Finally, thanks to the *Montreal Declaration for a Responsible Development of Artificial Intelligence* and the efforts that will lead to it, the strength of its experts, the quality of its citizens' participation in the major debates, its cultural assets and the strength of its AI ecosystem, Quebec will be perfectly positioned to take a leading role in the development of responsible AI across Canada and internationally. The province must be given the means to fully take up this leadership role.

SUGGESTED APPROACH

To position Quebec as the leader in responsible AI:

1) **We recommend that the Quebec government support the creation of an international prospective observatory on the responsible development of AI and the societal impacts of AI and digital technology.** This observatory would be a non-profit organization.[56] To avoid any perception of a conflict of interest, the governance of this entity should be independent from the AI and data science research organizations (e.g., IVADO and MILA) as well as corporations and AI.Quebec (see Recommendation 12), while still being linked operationally with the ecosystem's various components (in particular, the observatory should bring together several major university or college stakeholders). Moreover, this observatory should be in contact with all the stakeholders concerned by the societal, social, economic, cultural and ethical issues of AI use and development, i.e. interested stakeholders from academia, government, industry and civil society. Governance ensuring a diversified representation wherein none of the stakeholders have a majority control will ensure the necessary independence. The observatory's mandate will be divided into three components:

   a. Generate new knowledge on AI ethical and social issues and impacts by monitoring, listing and analyzing initiatives in this area at the national and international levels, and by working in partnership with the Fonds de recherche du Quebec (FRQ), through targeted calls for inter-institutional and intersectoral research projects in responsible AI.
   b. Continue the long-term efforts undertaken with the drafting of the *Montreal Declaration for a Responsible Development of Artificial Intelligence* by setting up a permanent forum where all stakeholders in Quebec society can debate the ethical and social issues related to the development and use of AI tools, as well as their impact. This citizen forum will, with input from AI ethics, law and technology innovation experts, make it possible to update the *Declaration* on a regular basis, an essential element in a context of accelerated and disruptive technological development.
   c. Make recommendations regarding legislative frameworks and public policies to be adopted to ensure the responsible use of AI and promote the successful adaptation of Quebec and Canadian society to the increasing penetration of AI in all spheres of life and activity, including social justice and the sharing of prosperity.

[56] The Committee is pleased to note that, on May 4, the Chief Scientist and the three Fonds de recherche du Quebec (FRQ), in partnership with the MESI, invited the scientific community to respond to a call for proposals aimed at setting up the Observatoire international sur les impacts sociétaux de l'intelligence artificielle et du numérique, whose mission and mode of governance correspond broadly to the description presented above. Government assistance will consist of an operating subsidy of at least $1M, and up to $2M annually for five years, with the possibility of renewal.

This mandate will be executed in close collaboration with Canadian and foreign jurisdictions charged with overseeing the development of responsible AI. This observatory, by maintaining an active dialogue with citizens and by bringing together all AI stakeholders, will promote education, responsibility and empowerment within Quebec and Canadian society and ensure that the voice of citizens is taken into account in the development of AI. Therefore:

1) **We recommend that the Quebec government adopt vigorous measures to position Quebec as an international leader in the field of AI and responsible AI.** It would do this by facilitating, as announced in its 2018-2019 budget, the implementation by Montréal International of a new international AI organization, as well as by supporting the strong participation of Quebec AI ecosystem members in the main existing Canadian and international forums regarding the social issues of AI use and the standardization bodies concerned by these issues. It should be noted that the establishment of a new international AI organization is distinct from the proposed observatory initiative, but the presence of an observatory, in addition to the scientific and industrial AI assets in Quebec, represents a pull factor for an international organization.

In the context of its efforts to become an exemplary AI user:

2) **We recommend that the Quebec government adopt a framework for the responsible use of AI** in which it undertakes to the following:
    a. Increase the internal expertise of ministries and agencies regarding the responsible use of AI.
    b. Ensure that the anonymised data it generates are made available in an efficient manner that respects the privacy of citizens.
    c. Make public every use it makes of AI algorithms to come to decisions that may affect the lives of citizens.
    d. Give researchers the opportunity to examine these algorithms to detect problems that may affect their functioning.

    The Quebec government must apply this last recommendation quickly, to reassure citizens regarding the use it intends to make of the data that will be made accessible (see Recommendation 6) and the AI tools that will be created in Quebec, in some cases, with these data

.

Act internationally on issues related to artificial intelligence

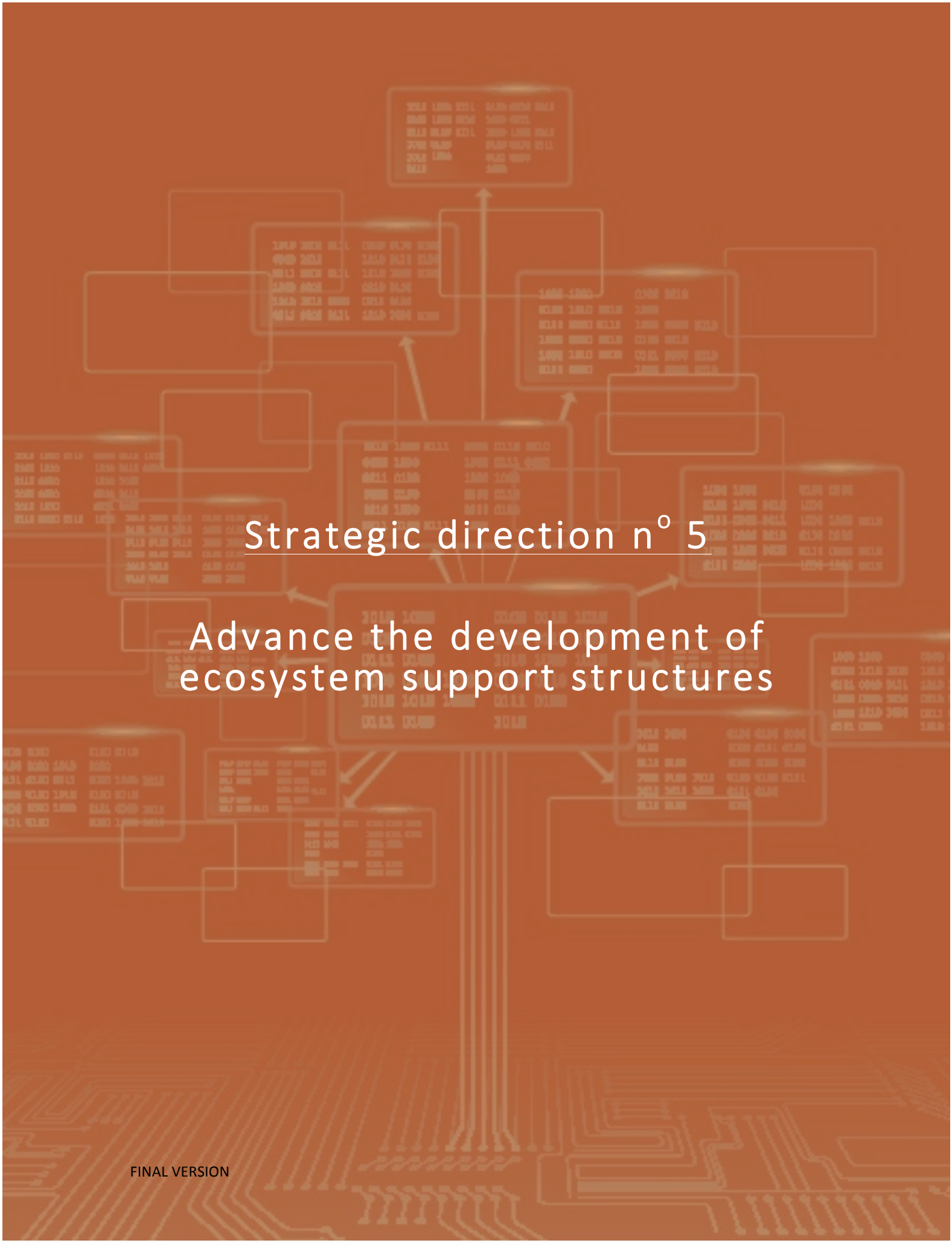
During a visit he made to France in March 2018, the Premier of Quebec proposed creating a global organization that would work on societal and ethical issues related to the development and use of AI. According to the Quebec government, this would be a sort of "control tower" that could "reassure the public" about the evolution of this new technology, among other things.

In its 2018-2019 budget, the Quebec government followed up on this announcement by earmarking $5M for Montréal International "to facilitate the establishment of a new international artificial intelligence organization in collaboration with key stakeholders in the field,"[57] including the Steering Committee.

The Steering Committee is of the opinion that the setting up of such an organization and its presence in Quebec would have very positive impacts. It intends to provide all possible support Montreal International needs to make this initiative a success.

The Committee also believes that it will be important for the government to give Quebec's AI stakeholders, from companies to research centres to ministries and agencies, the means to intervene forcefully in influential Canadian or international forums, such as the Partnership on AI (a group founded by major U.S. digital companies that today includes such players as the Association for the Advancement of Artificial Intelligence, the Fraunhofer Institute for Industrial Engineering, Element[AI], McKinsey & Company or Accenture), as well as standardization bodies involved in the effective and responsible development of AI (see "AI standards" on page XX of the Appendices).

[57] See http://www.montrealinternational.com/a-propos/salle-de-presse/de-nouvelles-mesures-pour-renforcer-le-bassin-de-talents-internationaux-et-mettre-en-place-une-organisation-internationale-en-intelligence-artificielle/.



Strategic direction n° 5

Advance the development of ecosystem support structures

FINAL VERSION

> Recommendation 10: Ensure access to computing power and computational expertise for AI and data science stakeholders

$100M fund financing priority

FINDINGS

In the AI sector, many research and technology developments rely heavily on its researchers' and application developers' access to computing infrastructures that are as robust as they are safe, in short, on connectivity, computing power and high-quality data storage services.

Compute Canada is the organization responsible for coordinating the delivery of advanced computing services across Canada. This NPO has four regional partners: ACENET in the Atlantic Provinces, Calcul Québec, Compute Ontario and WestGrid, each supported by government partners and other stakeholders.

Calcul Québec is a group that brings together Quebec universities that share advanced computing infrastructure. Calcul Québec has a core group of highly qualified experts who can support AI researchers in their work.

Despite the efforts made by Canada and Quebec to ensure a balance between the supply of computing power and the needs of researchers and companies, significant obstacles often prevent them from having access to all the resources they need to carry out their AI projects.

First, it seems only 30% of graphics processing units (GPUs) and 50% of CPUs (central processing units) needed by Quebec research centres and groups are currently available.[58] The investments announced by the federal government in its 2018-2019 budget (see the text box below) should prevent the extension of the gap between Quebec and Canada and their international rivals in terms of computing power. This alone will not meet all the AI ecosystem stakeholders'future demand since their needs will grow rapidly.

The federal government and computing power

in its 2018-19 budget, the federal government announced $572M over five years to implement a new strategy for digital research infrastructure and big data use in collaboration with the provinces, universities and players like Compute Canada and the Canada Foundation for Innovation. The details of this strategy and the amounts that will be injected into Quebec will be known at a later date.

Second, currently, the activities of computing power providers, such as Calcul Québec, cannot always be organized in a way that meets all the GPU or even CPU requirements of AI players. For example, according to AI players, the reported wait time to access the GPU required for a project is often too long.

Moreover, Quebec's AI stakeholders, especially SMEs, do not always have the necessary knowledge to structure their IT assets and activities (e.g., their cloud computing or data anonymization and protection

[58] Results of the last Compute Canada award process, estimated by Calcul Québec.

activities) and properly leverage the computational power Calcul Québec and other providers (e.g., Amazon Web Services) currently offer.

At the moment, Calcul Québec would not be able to respond in a flexible way to the emerging and growing needs of researchers (in AI as well as in sectors like transportation, health and law, where AI tools are increasingly being used), as well as those of start-ups and established SMEs who would like to get coaching to understand the full range of computing resources available on the market and make wise choices.

That being said, challenges are the same elsewhere in Canada. To meet these challenges, Ontario decided in 2014 to confer NPO status on Compute Ontario and invest $75M over five years to implement its strategy.

SUGGESTED APPROACH

To correct the shortcomings mentioned above:

1) **We recommend that Quebec's computing infrastructure needs be clearly defined and that appropriate representations be made to the federal government to ensure that Quebec receives an appropriate share of the funding provided by the federal budget.** In its 2018-19 budget, the Government of Canada has proposed $572.5M over five years and $52M per year thereafter to implement a digital research infrastructure development strategy. This strategy aims to provide Canadian researchers with more open and equitable access to advanced computing resources and big data. The Canadian Minister of Science has announced his intention to work with stakeholders, including the provinces and universities, to produce this strategy and define the role that players like the Canada Foundation for Innovation, Compute Canada and the Canadian Network for the Advancement of Research, Industry and Education will play in its application.

2) We also recommend that Quebec's AI researchers who use AI techniques in their field of research, as well as the companies that work with these researchers on collaborative research projects, have access through Calcul Québec to the increased graphics processing units (GPU) and greater storage capacities they require.

3) **Finally, we recommend supporting Calcul Québec in strengthening its capacity to effectively support researchers and businesses within the AI ecosystem in particular.** Among other things, it would be appropriate to:
    a. Actively participate in ongoing discussions regarding governance models for Canada's digital research infrastructure to influence the developments that will happen across the country and ultimately increase Calcul Québec's flexibility and agility.
    b. Ensure Calcul Québec has the means to set up and roll out a larger team of advisers whose role would be to support research centres and groups, as well as Quebec companies, in the design and implementation of optimal strategies for high performance computing. For instance, this team could provide information to AI stakeholders about solutions offered by other providers (e.g., help them work with private storage, computing and data protection service providers).
    c. Support Calcul Québec in revising its mission or strategy to help it determine how best to ensure its long-term funding.

Note that the possible reorientation of Calcul Québec and the reinforcement of its capacity to help AI companies could help boost Quebec's high-performance computing ecosystem, particularly through the

growth of computing, data protection and other service providers with whom Calcul Québec will work closely together.

> Recommendation 11: Create a permanent AI.Quebec organization with its own administrative structure to play a monitoring role and facilitate coordination between Quebec AI ecosystem stakeholders

FINDINGS

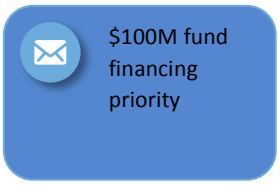
In Quebec, a promising support ecosystem for the development of AI already exists, which includes players in private finance, technology transfer and training, as well as business associations and sector clusters. As noted in this report, many ongoing and upcoming non-governmental initiatives are expected to allow this support ecosystem to grow to adequately support AI growth in the province. However, failure to implement these projects could seriously jeopardize Quebec's future leadership in AI.

Moreover, while the many stakeholders in the Quebec AI ecosystem is a major asset, it also raises some problems. Despite its many strengths, Quebec has limited resources compared to players like China or the United States. Therefore, it is all the more critical to optimize these assets and coordinate the efforts of the ecosystem.

Also, in a sector that is evolving as rapidly as AI, and in digital sciences in general, the ecosystem's directions must be flexible. We don't know where the next scientific breakthrough or the next "Facebook" will come from, but it's possible to set up a flexible and agile system that can adjust quickly to provide adequate support to new players with strong potential or improve the ecosystem's strategy.

Finally, not only is it essential to support the growth of the Quebec AI ecosystem, but significant marketing efforts must be made to ensure its visibility on a global scale. Some actors are already mobilized and are engaged in promotion internationally, but they will need adequate support to have sufficient striking force.

SUGGESTED APPROACH



We recommend the creation of "AI.Quebec", an administrative entity with a strategic reflection, rallying and promotion role, which will work in close collaboration with all the governmental and non-governmental stakeholders concerned by the development of AI in Quebec, from the QuebecInnove network to TechnoMontréal, Montreal International, Québec International, Prompt or the ministries of Economy, Science and Innovation, Education and Higher Education, International Relations and La Francophonie or Labour, Employment and Social Solidarity. More specifically, AI.Quebec would have the following responsibilities:

1. Continue, through collaboration, the **strategic efforts** to create, in Quebec, the largest artificial intelligence ecosystem in North America.
    a) To this end, we suggest AI.Quebec play a monitoring role with the aim of continuously evaluating the robustness of the support ecosystem. The organization can recommend specific actions to the government to address any shortcomings observed. Areas in need of monitoring include access to financing capital, access to computing infrastructure,

upgrading of technology transfer actors, technology transfer mechanisms, awareness within large companies and the availability of consulting services for SMEs.

b) AI.Quebec would also be mandated to monitor international AI developments and then inform the ecosystem and the government of the issues and opportunities for research and the Quebec economy.

c) Finally, AI.Quebec would be responsible for continuing the ongoing strategic effort, regularly reviewing the ecosystem's five-year plan and sustaining the vision's implementation overall.

2. Lead the "**talent watch**" mentioned in Recommendation 3 to ensure the ecosystem's robustness in terms of talent and training.
3. Ensuring **solidarity, collaboration and cooperation** of Quebec AI stakeholders. To this end, AI.Quebec would be in charge of facilitating current and future ecosystem player networking, act as a mediator in the event of litigation and serve as a central body around which ecosystem players can rally to resolve the issues together. As such, AI.Quebec would also be responsible for setting up and updating the common technology showcase presented in Recommendation 12.
4. Build bridges between Quebec's AI ecosystem and other AI ecosystems around the world, starting with other Canadian ecosystems. AI.Quebec must stay in constant communication with the Canadian AI Consortium and the federal government to ensure a pan-Canadian network of initiatives affecting the provinces.
5. Play a supporting role in promoting Quebec's AI ecosystem in Canada and abroad. We suggest that AI.Quebec support existing partners in their efforts to promote AI, e.g., Montreal International. AI.Quebec's administrative body could also support the government in its representation roles at the federal and international levels.
6. Support the coordinated participation of Quebec in some of the key Canadian and international forums on the future of AI and this new industry's development. In particular, Quebec should ensure, through AI.Quebec and the new international observatory on responsible AI and its impacts, to have a strong say at Canadian and international standardization negotiation tables implemented over the recent years and months to provide a framework for the design of AI tools and their ethical use (see the text box below).

AI.Quebec's precise governance model will be adopted during the implementation of this strategy, in close consultation with all ecosystem stakeholders.

Quebec and AI standards

Quebec will benefit from participating in the standardization efforts that will be undertaken in the AI sector. The process will enable Quebec researchers and companies:

- To be among the first to know which standards will direct the evolution AI so that they can quickly adapt to the future requirements of the international market.
- To influence standardization processes so that certain issues important for the development of the Quebec AI market and industries that use AI, as well as for the development of Quebec society and culture are addressed adequately (e.g., speech recognition or synthesis software able to process Quebec French effectively).

Therefore, it will be important for Quebec to ensure a strong Canadian representation on ISO's new

Artificial Intelligence Committee (SC 42 JTC 1), as well as other standardization jurisdictions. This representation should also take Quebec's interests into account and, above all, ensure the effective transfer of acquired knowledge to all Quebec stakeholders. In coordination with the Alberta and Ontario AI clusters, Quebec could work to define an intervention plan in the ISO SC 42 Committee and other standardization bodies.

Quebec and Canada could take steps to implement a modest consultation and dissemination structure to gather input from AI ecosystem stakeholders and quickly inform them of the work being done by standardization bodies and the impact of this work. Finally, it may be a good idea to foster collaboration between Quebec an other countries, such as France, to ensure that issues of cultural and linguistic diversity are properly addressed in AI.

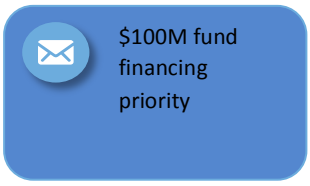
> Recommendation 12: Facilitate access to information on available resources for AI ecosystem stakeholders and promote connections between them through a common showcase

FINDINGS

A rich and complex ecosystem of intermediaries exists in Quebec, but this ecosystem is currently fragmented, with no clear "gateway" for non-technology companies of all sizes. While a portal for businesses, QuebecInnove, exists, this platform is not currently able to receive, filter and route AI requests, which adds a level of granularity. Lack of clarity regarding "who does what" ensures that many requests are routed to MILA and IVADO without their having the capacity to respond. Therefore, it is crucial to set up an effective networking mechanism tailored to end-user needs.

As mentioned in this report's recommendations, increased visibility for all the AI ecosystem's resources would make the journey easier for the following stakeholders: local and international students, business leaders, professionals looking to convert their skills, etc.

SUGGESTED APPROACH



We recommend the creation of an online showcase platform that would be accessible on the AI.Quebec and Entreprises Quebec sites. On the sites, the following would be accessible:

- Each player's offering in marketing and technology transfer
- A list of AI start-ups in the ecosystem and their respective sectors
- A list of the existing provincial and federal grant programs and their target audiences
- A list of the academic research topics in AI available in Quebec, including a list of researchers working in each field
- A list of internships available for local and foreign students
- The scholarship and funding offerings available to local and foreign students
- Future profiles in AI
- A list of all existing AI and digital science training courses, either credited (college, university, continuing education) and non-credited (e.g., online courses on AI's transformation potential).

This platform must meet several criteria to achieve its main objective, which is to bring together investors, creators and potential users, and increase the visibility of available academic research and training programs. The platform should reflect the image of the ecosystem, i.e. modern and easy to use. It must be inclusive and apply across Quebec as a whole and should highlight existing technology transfer models. The platform will also need to be updated frequently, if not automatically. Finally, the platform must promote awareness and education, i.e. explain what AI is, describe the applications of responsible AI and provide the appropriate educational material to inform the Quebec population about the various typical AI use cases according to sector.

Conclusion

Concluding remarks

The development of Quebec's AI strategy is the result of collaboration between the Steering Committee members and Quebec ecosystem stakeholders who, in addition to their respective roles as investors, entrepreneurs, employers, researchers or professors, came together with the common goal of ensuring future progress and prosperity for our society. Indeed, many members of the academic, industrial and governmental sectors were involved in the development and validation of this report's 12 recommendations in the hope of helping Quebec become the most important artificial intelligence ecosystem in North America. Our community will benefit greatly from the commitment of all the leaders who have shared their point of view on the issues, challenges and opportunities for Quebec and all of its regions in the development of an AI hub in Quebec.

Talent is the sinews of war. It is a finding, an issue, even an opportunity that is unanimously accepted in the Quebec AI ecosystem.

Quebec's success will depend directly on its ability to train and attract the talent needed for basic AI research, the design of applications that use AI algorithms and the adoption of AI and AI-related technologies by Quebec businesses. Also, the creation of a pool of talent is necessary, but insufficient to enable Quebec to take advantage from the significant potential economic benefits generated of the commercialization of AI solutions. The main strategic directions of this report reflect this vision by first emphasizing the growth and durability of an AI research hub in Quebec, the development of talent in digital sciences throughout Quebec and the accelerated adoption and development of these new technologies by the entire Quebec economy. It will be essential to proactively address the issue of responsible AI with the community, given the societal change that will result from the use of AI. Finally, these four strategic orientations require facilitating elements, such as access to suitable computing power, which will also need support to develop.

The Steering Committee will continue its work in the coming weeks. Among other things, it will sollicit government input and work closely with government and ecosystem stakeholders to support the implementation of the recommendations.

Some of the approaches suggested in this report can, and *must*, be carried out quickly to allow Quebec not only to stay in the global race for AI excellence, but also to become a leader in this field.

Here is an overview of the actions we recommend the government implement within six months of the tabling of this report.

Proposed plan for the next six months

As mentioned in the introduction to this report, some of our recommendations involve long-term initiatives, while others are achievable in the immediate future. To ensure the fast and effective implementation of the elements that can emerge in the near future, here is a list of announcements the MESI should make and concrete actions it should take within six months of the tabling of this report.

First, the MESI should:

1. Publicly announce the report's main directions.
2. Decide on an incremental timeline and funding scheme (to achieve funding sustainability over 10 years and increase the budget envelope for the development of the AI ecosystem.
3. Announce the funds granted to the MILA – Quebec Artificial Intelligence Institute to support its development.
4. Announce its support of SCALE.IA.
5. Announce the creation of the AI.Quebec group by the end of 2018.

Subsequently, the MESI will need to act upon the report's strategic directions and:

1. Allocate the appropriate grants to the MILA – Quebec Artificial Intelligence Institute.
2. Allocate the appropriate level of grants for the operationalization of SCALE.AI.
3. Support the creation of a permanent AI.Quebec administrative body to serve as a mobilizing force.
4. Give AI.Quebec the mandate to set up a "talent watch" with the support of TECHNOCompétences.
5. Launch the program for the creation of AI sectoral chairs.
6. Work with the Ministry of Immigration, Diversity and Inclusion to add AI faculty and researchers and other AI specialists to the "Volet talents mondiaux" list of occupations to speed up the immigration process.
7. Set up a government budget envelope to support Quebec's educational institutions in updating their training offerings.
8. Simplify and accelerate the government approval process for training programs offered by Quebec educational institutions.
9. Approach the Chief Information Officer of the Conseil du trésor du Quebec to undertake a strategic planning effort for AI adoption by the Quebec government.
10. Set up marketing and technology transfer support programs (private-private project financing and sectoral support programs).
11. Announce the launch of the observatory on socially responsible development of AI and on the impacts of AI, and mandate a think tank on the international positioning of Quebec in this area.
12. Follow up on the Premier's announcement regarding the establishment of a global responsible AI organization in Montreal.

Proposal for the allocation of the $100M from the MESI and details regarding the need for an additional $300M

In light of the strategic directions presented in this report, below are our allocation recommendations for the $100M budget envelope earmarked for the development of the Quebec AI ecosystem.

First, the Steering Committee is convinced that the development of the Quebec AI ecosystem will be driven by the rise of the MILA – Quebec Artificial Intelligence Institute and therefore recommends the allocation of:

- $80M to support the development of MILA – Quebec Artificial Intelligence Institute, with an initial amount of $65M and a conditional balance of $15M upon meeting certain milestones (to be established with the MESI). The development of this Institute is the spearhead of the strategy for the development of the AI in Quebec and serves multiple strategic directions outlined in this report: the establishment of a research hub, talent development, the hiving off of AI start-ups, the adoption of AI skills by the Quebec technology transfer network, making an important contribution to the debates regarding responsible AI and providing better access to computing power and computational expertise to AI researchers.

Also, we consider many of the initiatives mentioned in the recommendations as priorities. These initiatives will require timely financing totaling $20M, for which we recommend the following breakdown:

- $ 10M to support the marketing and adoption of AI solutions, including:
    - Financing of sectoral support programs for companies looking to make an AI shift.
    - Financial support (via tax credits) for Quebec businesses that meet their AI needs through local start-ups or SMEs.
- $4M to set up a permanent AI.Quebec administrative body
    - This estimate takes into account the salaries of a team made up of a few people and a budget to carry out the various activities of the organization.
- $3.5M for the establishment and operation of an international observatory on responsible AI and AI impacts.
- $2.5M for a series of impactful ecosystem initiatives:
    - Implementation of the “talent watch” that would quickly conduct a study to determine the industry's needs in terms of AI and AI-related profiles and skills, with a view to matching training to employment.
    - Upgrading AI technology transfer organizations using a train-the-trainer approach.
    - Establishment of the “AI.Quebec” common platform, which will list the various ecosystem stakeholders and their service offerings.
    - Financial support to colleges and universities to support them in quickly updating their training offering.

Therefore, as outlined in the table below, the MILA should receive up to $80M of the $202M the Quebec government has so far earmarked for AI development in Quebec, or 39.6% of the available budget envelope

Quebec government AI investments

Actions	Amount allocated (in $M)	Percentage of total investment
$100M fund financing priority Support the development of the MILA	80.0	39.6%
$100M fund financing priority Creation of an international observatory on responsible AI and AI impacts	3.5	1.7%
$100M fund financing priority Implementation of AI.Quebec	4.0	2.0%
$100M fund financing priority Support for AI marketing and adoption, including the financing of sectoral support programs for companies who want to shift to AI.	10.0	5.0%
$100M fund financing priority Support for other initiatives, namely the establishment of a "talent watch," modernize AI transfer organizations, set up a common platform and support rapid updating of educational institutions' training offerings	2.5	1.2%
Other AI investments – Launch of SCALE.AI project, AI-optimized procurement chains	60.0	29.7%
Other AI investments – Creation of the International AI Organization in Montreal	5.0	2.5%
Other AI investments – Applied math to support AI-related fields in Quebec	1.0	0.5%
Other AI investments – Digital economy action plan, measure 1; support for the IVADO project (Canada First) and Calcul Québec	5.0	2.5%
Other AI investments – Digital economy action plan, measure 3; support for collaborative research projects via Prompt	8.5	4.2%
Other AI investments – Development of the computing infrastructures required for AI's development	12.5	6.2%
Other AI investments – Launch of HEC Montréal's Creative Destruction Lab Montréal and of NextAI Montreal	10.0	5.0%
Total Quebec government funding for the development of AI in Quebec	**202**	**100.0%**

In addition to the $202M detailed above, we strongly believe that an additional investment of approximately $300M is needed to help Quebec become a leader in AI. This additional amount will serve three major purposes:

1) About 50% of these funds should go towards the sustainability of the ecosystem's anchoring institutions (i.e. to support the MILA and IVADO over a 10-year period), strengthen Calcul Québec's ability to meet the needs of its partners (particularly SMEs) and ensure the creation and operation of AI.Quebec and the international observatory in responsible IA.

2) 20% of the additional investment would be used to increase the development of AI and digital science talent in the ecosystem, including the creation of sectoral chairs to develop an AI application research hub, funding support for additional university and college faculty positions, as well as bringing together and ramping up democratization of science and mathematical literacy initiatives.
3) And, 30% of the funds would be used to accelerate the development and marketing process of Quebec AI solutions and, especially, their adoption by organizations that make up Quebec's economic network. In concrete terms, this would mean earmarking an additional budget envelope to directly support companies in marketing their AI innovations, roll out sectoral programs to support the use of AI and to develop the capacity to adopt AI of Quebec's ministries and agencies.

Appendices

Summary of recommendations and suggested approaches

STRATEGIC DIRECTION 1:

Ensure the development and sustainability of Quebec's AI academic research hub

Recommendation 1: Attract researchers

- Support the development of the MILA – Quebec Artificial Intelligence Institute
- Create excellence chairs by sector
- Support the creation of academic positions (universities)
- Set up a permanent chair program
- Support the recruitment of university researchers
- Support the recruitment of professors/researchers within the college network
- Add AI professors and researchers to "Volet talents mondiaux" professions list

Recommendation 2: Attract master's and doctoral students

- Increase the visibility of research opportunities in AI and related fields
- Increase financing for master's and doctoral
- Increase foreign student retention programs

STRATEGIC DIRECTION 2:

Develop digital science talents to meet Quebec's needs

Recommendation 3: Develop and maintain a "talent watch"

- Implement and roll out a "talent watch"

Recommendation 4: Support the updating of training offerings

- Support for the creation and modification of programs (does not include future online courses)
- Simplify and speed up government approval of training programs educational institutions propose

Recommendation 5: Promote mathematical literacy and the democratization of science

- Set up an organization to coordinate and promote the striking force across Quebec

STRATEGIC DIRECTION 3:

Accelerate the development and adoption of AI solutions within Quebec's economic fabric

Recommendation 6: Support AI design businesses

- Create data trusts
- Provide start-ups with priority access to Calcul Québec and Compute Canada
- Subsidize partnerships between start-ups and private entreprise
- Review the government's strategic procurement mode à
- Implement marketing tax credits or funding programs

Recommendation 7: Support future private sector AI users

- Modernize the selected intermediary organizations
- Support intermediaries in implementing consulting teams
- Set up sector-specific AI shift coaching programs
- Consider consolidating many technology transfer sector organizations into an applied research institute

Recommendation 8: Government and Crown corporations as model AI users

- Implement the action plan on AI solution adoption within the government apparatus
- Modernize regulations regarding the use of public data

STRATEGIC DIRECTION 4:

Develop an international responsible AI and AI impact analysis hub in Quebec

Recommendation 9: Sustainability of mobilization efforts regarding responsible AI

- Creation of an observatory on responsible AI development and AI impact
- Position Quebec as an international leader in responsible AI

STRATEGIC DIRECTION 5:

Advance the development of ecosystem support structures

Recommendation 10: Access to computing power and computational expertise

- Support the development of Calcul Québec

Recommendation 11: Creation of a permanent AI.Quebec administrative body

- Provide financing of AI.Quebec

Recommendation 12: Access to information on a common platform

- Create the AI.Quebec platform

Steering Committee members

Business sector

Pierre Boivin

(Committee Co-Chair)

President and CEO

Claridge inc.

Chris Arsenault

Managing Partner

iNovia

Thomas Birch

Vice-President, Funds and Technologies

Caisse de dépôt et placement du Quebec

Magaly Charbonneau

Principal

iNovia, entrepreneur, (PasswordBox acquired by Intel)

Patrick Pichette

Corporate Director and Strategic Advisor

Valery Zamuner

Vice-President, Mergers, Acquisitions and Strategic Initiatives

Stingray

Charles Boulanger

CEO

LeddarTech

University sector

Guy Breton

(Committee Co-Chair)

Rector

Université de Montréal

François Bertrand

Director, Research, Innovation and International Affairs

Polytechnique Montréal

Martha Crago

Vice-President, Research and Innovation

McGill University

Robert Gagné

Director, Research and Transfers — Chair of the Governing Board

HEC Montréal – IVADO

Marie-Josée Hébert

Vice-Rector, Research, Discovery and Innovation

Université de Montréal

Observers

Gilles Savard

General Manager

IVADO

Yoshua Bengio

Scientific Director

MILA,

Université de Monréal

Doina Precup

Associate Professor, IT School

McGill University

Marie-Josée Blais

Assistant Deputy Minister

Ministry of Economy, Science and Innovation

Mario Bouchard

Assistant Deputy Minister

Ministry of Economy, Science and Innovation

List of people met during our work

Amyot, Robert – CAE

Anglade, Dominique – Ministère de l'Éducation, de la Science et de l'Innovation

Baillet, Francis – Ubisoft

Barette, Gaétan – Ministère de la Santé et des Services Sociaux

Bastien, Frédéric – MILA et Université de Montréal

Bastien, Frédéric – Mnubo

Beaudoin, Josée – CEFRIO

Béliveau, Louise – Université de Montréal

Bellemare, Alain – Bombardier

Benoit, Suzanne – Alliance Numérique

Béraud, Frank – Montreal In Vivo

Bernstein, Albert – CIFAR

Bertrand, François – Polytechnique Montréal

Bérubé, Vincent – McKinsey & Compagnie

Blais, François – Ministère du Travail, de l'Emploi et de la Solidarité sociale

Boel, Nicolas-Louis – Altissia

Boivin, Benoit – Secrétariat du Conseil du Trésor

Bolduc, Hubert – Montréal International

Borrelli, François – Prompt

Boufaden, Nariés – Keatext

Boulet, Benoît – Université McGill

Brodeur, Pierre – Regroupement des collèges du Montréal métropolitain

Brouillet, Eugénie – Université Laval

Brunel, Benoit – Bonjour Santé

Brunelle, Eric – Druide Informatique

Brunelle, Martin – Desjardins

Bruno, Richard – CIRANO

Cai, Changtian – Huawei Thechnologies

Carignan, François – Purkinje

Carle, Sylvain – Aero Montréal

Chagnon, André – SOJECCI

Chapados, Nicolas – Imagia

Chenette, Madeleine – Accenture

Clark, James – Université McGill

Clerk, Maxime – Prompt

Cléroux, Louis – Blockchain Superclus

Coiteux, Martin – Ministère des Affaires municipales et de l'Occupation du territoire

Corbo, Jacomo – Quantum Black

Côté, Diane – MEDTEQ

Côté, Myriam – MILA

Cournoyer, Jean-Sébastien – Element AI

Courville, Aaron – MILA et Université de Montréal

D'Amours, Sophie – Université Laval

Debbabi, Mourad – Université Concordia

Deguire, Charles – Kinova

Delage, Jean-Nicolas – Notman – OSMO

Desbiens, Denis – IBM

Desmarais, Hélène – Centre d'entreprises et d'innovation de Montréal

Divry, Lidia – TechnoMTL

Dumouchel, Pierre – ETS

El Asri, Layla – Microsoft

Émond, Marie-Claude – Alliance Numérique

Faubert, Denis – CRIAQ – Most 21

Fortier, Suzanne – Université McGill

Gagné, Christian – Université Laval

Gagné, Jean-François, Element AI

Garinis, Tom – Deloitte

Gauthier, Johanne – MTESS

Girard, Anne-Marie – Université de Montréal

Gravel, Vivianne – B-citi

Grégoire Rousseau, Jean-Sébastien – McKinsey & Compagnie

Halinaty, Mark – Thales Canada

Hamel, Manon – Caisse de dépôt et placement du Québec

Houle, Sébastien – Productique

Huneault, Michel – ETS

Jacques, Pierre-Étienne – Université de Sherbrooke

Jaskolka, Norman – Aldo

Klugman- Iain – Communitech

Labonté, Françoys – CRIM

Lacoste-Julien, Simon – MILA et Université de Montréal

Lajoie, Gilles – SOQUIJ

Lalonde, Fred – GERAD

Lamothe, Marie-Josée – Google Canada

Lanoue, Josée – TechnoCompétences

Laportevation, Réal – Hydro-Québec

Larochelle, Hugo – MILA et Google Canada

Laviolette, François – Université Laval

Lavoie, Alain – Irosoft

Lavoie, Valérie – Fédération des cégeps

Le Bouthillier, Alexandre – Imagia

Leblanc, Martin – Caprion

LeCun, Yann – Facebook

Létourneau, Stéphane – Université de Montréal

Lévesque, Louis – Finance Montréal

Lodi, Andrea – Chaire CERC, Polytechnique Montréal

Martel, Nicole – AQT

Masson, Alexandra – Québec International

Mauro, Andy – Automat.a

Molaret, Philippe – Thales Canada

Montini, Emmanuel – Cégep de Bois-de-Boulogne

Moravei, Amir – Botler/Nomino

Musbah, Mohamed – Microsoft

Noël, Jean-François – MEES

Pal, Christopher – Polytechnique Montréal

Parent, Marc – CAE

Park, Thomas – BDC Capital

Patry, Michel – HEC Montréal

Perreault, Jean-Pierre – Université de Sherbrooke

Pilon, Pascal – LANDR

Pineau, Joëlle – MILA et Université McGill

Poulin, Daniel – LEXUM

Poulin, Geneviève – Ubisoft

Prodromou, Evan – Fuzzy.ai

Raimondi, Patrick – Accenture

Rigazio, Luca – Panasonic

Roy, Louise – Université de Montréal

Sabia, Micheal – Caisse de dépôt et placement du Québec

Schlesinger, Adam – Banque Nationale du Canada

Schuler, Cameron – AMII

Sherry, Dave – Lightspeed

Sirois, Luc – Prompt

Smirnov, Alexis – Dialogue

Talon, Suzanne – Calcul Québec

Tarnowski, Marcos – McKinsey & Compagnie

Têtu, Louis – Coveo

Thérien, Denis – Université McGill

Tremblay, Jean-François – Institut de l'électrification

Trépanier, Martin – CIRRELT

Trischler, Adam – Microsoft

Usal, Siefried – Thales Canada (CortAIx)

Vachon, Louis – Banque Nationale du Canada

Vallée, Nathalie – Collège Ahuntsic

Veerman, Alan – Vector Institute

Viel, Carl – Québec International

Vigeant, Daniel – Collège Lionel-Groulx

Vigneault, Mathieu – Transtech

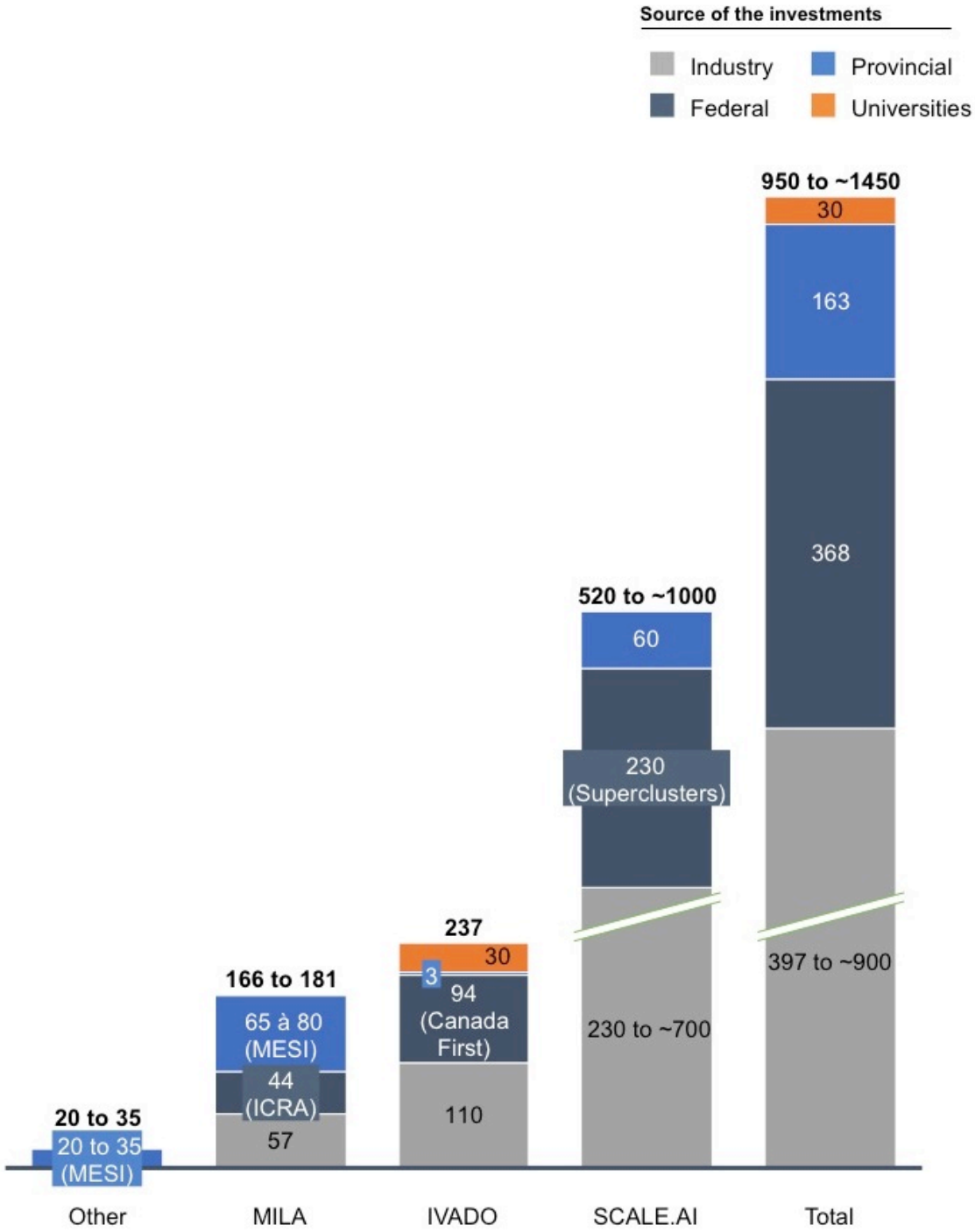
Vinet, Luc – CRM

Wallis, Jodie – Accenture

The Committee would also like to thank all the people who were met during the work on the Strategy for the Development of Quebec's Artificial Intelligence Ecosystem that are not mentioned in this list.

Overview of public and corporate financing

Figure 6 – AI organizations supported and source of the investments



Online courses

Quebec will benefit from its support of online course development as it will meet the training needs of all the AI ecosystem's human resources: pre-university graduates who want to become familiar with data preparation techniques, computer scientists eager to acquire machine learning skills to complement their basic skills, agriculture, health or transportation experts looking to use AI in their niche of expertise or managers who want to meet the strategic challenges of AI and AI-application use in their business.

First of all, the creation of French online courses – a subject in which Université Laval, HEC Montréal or Téluq possess enviable expertise – will make it possible to reach all Quebecers concerned by AI no matter where they live. While it will be relatively easy for workers and future workers in Montreal and other major urban centres in Quebec to take courses at MILA or other centres or in-person training institutions, some AI courses should also be offered virtually so that they are accessible to the greatest number of people, from Gaspésie to Outaouais to Les Bois-Francs. The rise of AI will affect all of Quebec's regions, and all of them should have easy access to high-quality online courses.

Some also believe that, given the right conditions, online courses can be an effective tool for attracting women to the field of AI. The flexibility offered by this training approach could help some women, including mothers, continue or resume their studies.[59]

The creation of French online courses will also be a great way to raise awareness and train members of La Francophonie who want to pursue a career in AI or better understand the technologies produced by this sector. In some cases, the online courses developed in Quebec will even encourage foreign students to complete their training locally, either in Quebec universities or colleges across the province. In fact, Quebec online AI courses could serve as a great calling card for our researchers, educational and research institutions and businesses.

In the short term, the creation of French online courses may even encourage organizations to adopt AI, since some of them are currently reluctant to provide instructor-led training for their employees lest they be recruited by the competition once their course is over.

For Quebec, the challenge over the next few years will not be to *direct* or *oversee* the efforts already undertaken by many of the province's academic, college and technical institutions to create credited and uncredited online AI courses that they will offer as part of their normal or continuing training programs.

However, the province should make resources available so that training stakeholders can develop high-quality online courses on strategic AI topics where needs do not match the training offering. This may occur because:

- Producing a very high-quality course can be expensive for an institution (an estimated $80,000 to $150,000).
- The initial demand for a course may be insufficient (too few students enroll in the first years).
- The demand for a course can be considerable without any return on investment (e.g., in the case of free or low-cost bulk courses, the expenses will obviously be greater than the revenues).

Therefore, if the "talent watch" reveals a lack of online courses, the Steering Committee will recommend the Quebec government create a budget envelope to support the development by Quebec's educational institutions of online AI courses to meet the various needs of Quebec organizations.

The management of this budget envelope could be entrusted to AI.Quebec, which, in close consultation with the industry and AI educational institutions, would issue calls for proposals to set up online courses in French, and possibly in other languages, such as English and Spanish, to train the human resources companies that develop and use AI will require at all levels

[59] See https://www.al-fanarmedia.org/2017/03/can-moocs-womens-entryway-stem/.

The amounts available should be used to create courses that will attract Quebec and foreign workers and students to the Quebec AI ecosystem, particularly university and college-based institutions that offer programs that will enable them to perfect their AI training.

In this respect, it would be a good idea to apply to the AI section the Jeunes leaders de la Francophonie framework that HEC Montréal and its partners advocate. Supported financially by Global Affairs Canada, this initiative aims to encourage start-ups in Benin, Burkina Faso, Haiti and Senegal. Ten thousand Francophones will begin by following a series of online courses for potential entrepreneurs. Then, the most promising students will receive support from tutors and mentors to produce a business plan and start their own business. The project's promoters hope that, in the long run, it will generate 240 new start-up companies in these four selected countries.[60]

Develop AI's French lexicon

The DataFranca project (www.datafranca.org), is supported financially by the Office québécois de la langue française, led by a team that includes an artificial intelligence and linguistics specialist and endorsed by companies like Google Brain Montréal. The project aims to develop French AI terminology through a participatory process.

The terminology produced by the experts will be used to create French Wikipedia articles on AI and improve existing Wikipedia articles. DataFranca managers will also distribute the results of this project on networks such as LinkedIn and reference resources such as the *Grand dictionnaire terminologique*. By supporting this initiative, the Office québécois de la langue française is helping Quebec society embrace a whole new industry (in the words of the promoters, to make it "as Québécois as maple syrup"), promote the transfer of AI knowledge to non-experts (French-speaking AI users, journalists, teachers), provide the framework for future French-language AI courses (e.g., for CEGEP students and AI users) and promote the coming in Quebec of "French-speaking brains" interested in AI.

[60] See http://fr.allafrica.com/stories/201710110712.html.

AI standards

The International Organization for Standardization (ISO) defines its standard as a "document, established by consensus and approved by a recognized body, that provides, for repeated and common use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of an optimum degree of order in a given context." The ISO adds that "[s]tandards should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits." [61]

Standards are usually published by national standardization bodies such as the Standards Council of Canada or international organizations such as ISO.

Standards can also be generated by a company that holds a strong competitive position (such as Microsoft), a professional association (such as the Institute of Electrical and Electronics Engineers or IEEE) or a consortium of companies (like the Canadian Wireless Telecommunications Association).

Standards are important because they lead to reduced risks for developers, promoters and users of a product or service. For example, setting standards on rail spacing supported the development of the U.S. rail industry. Indeed, before the spacing was set to 4'8 ½" at the end of the 19th century, trains could not necessarily move from one rail network to another. Similarly, setting rules about how much methylmercury is acceptable in fish that is sold protects the health of consumers.

In the technology sector, standards ensure the smooth running of the Internet, so that the same computer can seamlessly connect to the web from any country and any Wi-Fi network, help users learn new software (it's no coincidence that the Google Docs menu bar looks like Microsoft Word's, the leader in word processing software) and lets them use French or Chinese characters in a domain name.

The creation of specific AI standards has intensified in recent years. In 2017, the ISO set up Sub-Committee 42 (SC 42) to "[s]erve as the focus and proponent for JTC 1's [the reference body for the standardization of information technologies] standardization program on Artificial Intelligence" and "[p]rovide guidance to JTC 1, IEC, and ISO committees developing Artificial Intelligence applications."[62] For its part, the IEEE has just published the second edition of the *Ethically Aligned Design Report: A Vision for Prioritizing Human Wellbeing with Autonomous and Intelligent Systems (A/IS)*, which contains recommendations on strategies for designing intelligent and autonomous IT tools that take into account human values and which can gradually be translated into standards.[63]

In AI, standards can be used to ensure:

- That AI producers and users use common definitions and vocabulary to facilitate their exchange on the subject.
- That it is easier and cheaper to exchange and integrate the data required for AI development.
- That AI practitioners use exemplary design and production practices and, as a result, avoid suboptimal ways of doing things (such as over-learning or overfitting).
- That the risks associated with the emergence of new AI technology (e.g., self-driving vehicles) and methods to mitigate these risks be identified using specific and rigorous approaches;[64] and
- That the integration of fundamental ethical principles (e.g., equity) be done at the initial stages of tool design.[65]

[61] See https://www.cairn.info/revue-francaise-de-gestion-2003-6-page-49.htm.
[62] See https://www.iso.org/fr/committee/6794475.html.
[63] See https://ethicsinaction.ieee.org/.
[64] See https://arxiv.org/pdf/1709.02435.pdf.
[65] See https://www.techrepublic.com/article/ieee-announces-3-ai-standards-to-protect-human-well-being-in-the-robot-revolution/.