WGISTA

Working Group on Impact of Science and Technology on Auditing

Environmental Scan:

A report on SAI capabilities in emerging technologies and auditability in the public sector

INTOSAI
Goal Chairs
Collaboration
PSC – CBC – KSC

Annex-II

Quality Assurance Certificate of the Chair of the Working Group on Impact of Science and Technology on Auditing

This is to certify that ***Environmental Scan: A report on SAI capabilities in emerging technologies and auditability in the public sector (A Project Report)*** which is placed at level 3 of Quality Assurance as defined in the paper on "Quality Assurance on Public goods developed outside Due Process" approved by the INTOSAI Governing Board in November 2017 has been developed by following the Quality Assurance processes as detailed below:

(i) The project action plan was formulated by the Project Team, consisting of WGISTA Chair and Vice Chair, SAIUAE and GAO US, and approved by the WGISTA Chair in September 2020,

(ii) The project team developed the project report using three methods, namely, literature review, survey of SAIs and interviews with experts,

(iii) Following the protocol for QA level 3 documents; the Exposure Draft was circulated to all members of WGISTA for comments and feedback on January 5th,2023 to receive feedback by January 31st, 2023,

(i) This Endorsement version has been finalized by the project team after incorporating all the comments and feedback received from WGISTA members.

The product developed is consistent with relevant INTOSAI Principles and Standards. The structure of the product is in line with the drafting convention of non-IFPP documents.

The product will be subject to review and update every two years or as deemed necessary. As this paper is not directly linked to a specific ISSAI, no expiry clause is included.

[Signature of Chair]
H.E. Humaid Obaid Abushibs
Chair of WGISTA
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Quality Assurance Certificate of the Chair of the Knowledge Sharing and Knowledge Services Committee

Based on the assurance provided by the **INTOSAI Working Group on Impact of Science and Technology on Auditing (WGISTA)** and the assessment by the Goal Chair, it is certified that the **Environment Scan: A report of SAI capabilities in emerging technologies and auditability in the public sector (A project report)** which is placed at level **3 (three)** of Quality Assurance as defined in the paper on "Quality Assurance on public goods developed outside Due Process" approved by the INTOSAI Governing Board in November 2017, has been developed by following the Quality Assurance processes as detailed in the Quality Assurance Certificate given by the Working Group Chair.

The product developed is consistent with relevant INTOSAI Principles and Standards. The structure of the product is in line with the drafting conventions of non-IFPP documents.

The product will be subject to review and update every two years or as deemed necessary. As this paper is not directly linked to a specific ISSAI, no expiry clause is included.

Girish Chandra Murmu
Chair of Knowledge Sharing and
Knowledge Services Committee

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Executive Summary

Technology has evolved at an unprecedented pace. Emerging technologies like Artificial Intelligence, Blockchain and Robotic Process Automation are enabling governments to deliver services with speed and accuracy that has surpassed all previous capacities.

The auditing profession has been using technology to optimize its work for many decades now. But the newer technologies of the 4th Industrial revolution have posed unique challenges for auditors. They are now coming across implementations of emerging technologies in their work where they are expected to not only understand the General Computer Controls Risks but also comprehend the risks and controls associated with intelligent algorithms empowering solutions for service delivery.

INTOSAI being aware of these newer challenges created a new working group in 2019 to understand and research the impact of emerging technologies on auditing. The new working group called WGISTA (Working Group on Impact of Science and Technology on Auditing) has two main objectives:

- Auditing governments' treatment of these developments in their policies, regulations, and other relevant programs, and;
- Sharing best practices among auditors in developing and maintaining relevant expertise and applying science and technology in their auditing.

This Environment Scanning Report was developed as part of the WGISTA 2021-2023 Work Plan; as an attempt to understand the landscape of emerging technologies from a public sector auditor's perspective, to have insight into how SAIs are faring with respect to these technologies and to get expert views on best approaches to mainstream these technologies in public sector auditing.

The project was jointly led by the WGISTA Chair and Vice Chair, namely SAIUAE and GAO US. The report has been developed as per the requirements of Quality Assurance of products developed outside the Due Process - QA level3. It was shared with WGISTA members as required by the protocol and all comments received have been suitably addressed by project team.

The report was developed using three methods, namely: literature review, survey and interviews. A review of literature indicates that there are deficits in skills in overseeing, implementing and managing these emerging technologies. It has also been noted that some of these technologies have inherent characteristics that can support audits. An example in case is Blockchain technology which can provide transparency in transactions for auditors.

Literature Review also notes that Artificial Intelligence can be useful for auditors.[1] For example, skillful auditors could use deep learning methods for collecting and assessing audit evidence with greater speeds, bringing efficiencies to the auditing process.

[1]GAO. (2021, June 30). Artifical Intelligence: An Accountability Framework for Federal Agencies and Other Entities, GAO-21-519SP.

D.C., Washington. See appendix II in this report for a discussion on challenges associated with public sector use of AI.

The literature study also highlights the challenges associated with using these technologies.[2] Apart from gaps in skillsets, there are inherent challenges in some technologies too. For example, auditing AI based systems comes with a challenge of access to underlying algorithms because the inputs and operations of AI systems are mostly hidden from the end user.

Our Literature Review identified the following major risks and challenges related to these technologies from a public sector auditor's view point:

- Privacy, security and safety concerns
- Technologies are constantly evolving which makes it challenging to stay in step with latest developments
- Public sector entities may not have access to underlying algorithms logic and code because of intellectual property concerns.
- Historical bias in data may creep into AI systems which may impact individuals who would find it hard to confront because of a lack of adjudication process against AI systems.

We also surveyed Supreme Audit Institutions on their use and audit of emerging technologies. The survey responses clearly paint the picture of a fragmented landscape with individual SAIs trying to explore and experiment with latest technologies. We also noted that the SAIs are at different maturity levels with respect to the implementation of technology.

However, it is encouraging to remark that most SAIs are aware that we are in the midst of a technology revolution that is unlike the previous ones. We note interesting use cases of emerging technology implementation like RPA and AI. SAIs are also aware of the potential of Blockchain as a technology and many SAIs are exploring these emerging technologies.

We also reached out to experts/academicians to gather their views, especially about the potential of these technologies and the best approaches to upskill the work force when it comes to latest technologies. They are unanimous in their viewpoint that the pace of adopting emerging technology in the government sector will only increase.

Our experts also identified various sectors of government which are more likely to have a faster adoption of AI. The factors that can impact the speed of adoption and mainstreaming these technologies include reliability, effectiveness and auditability of these technologies. These experts also noted that government regulatory agencies can leverage AI- assisted auditing to address resource limitations.

Experts also highlighted different approaches to upskill the workforce. One option suggested by experts is micro-degrees in this field. The importance of creating a quality training program and the need for customizing the training according to training objectives was stressed by experts. Another possible strategic investment strategy that organizations could use is recruiting AI experts with a proven track record in data engineering and AI deployment who can then work with subject matter experts within the organization.

[2] GAO. (2021, June 30). Artifical Intelligence: An Accountability Framework for Federal Agencies and Other Entities, GAO-21-519SP. D.C., Washington.

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Introduction

The world of audit is undergoing a transformation due to the advent of new technologies. This transformation brings about new challenges and opportunities for the profession. As a result, it is important for audit practitioners to keep abreast of the changes taking place in the industry and adopt appropriate solutions to meet the needs of clients and improve the quality of audits.

In today's digital era, organizations are increasingly leveraging emerging technologies to achieve operational excellence and competitive advantage. However, the adoption of these technologies pose significant risks to the integrity of financial reporting and raise questions about whether existing controls are adequate.

In addition, many governments are now relying heavily on data generated by emerging technologies to make decisions. These factors require auditors to adapt new ways of working and new skills and processes.

As public sector auditors, we need to be aware of these developments and prepare ourselves to:

- Understand the nature and inner workings of these emerging technologies;
- Assess the impact of these emerging technologies on the design and delivery of public sector goods and services;
- Identify and mitigate key risks associated with emerging technologies; and
- Develop risk mitigation strategies

INTOSAI Working Group on Impact of Science and Technology on Auditing (WGISTA) undertook this research study to scan the technology environment related to emerging technologies from the viewpoint of public sector auditing profession.

INTOSAI is not the only professional body that is exploring the impact of latest technologies on auditing and accounting professions. In fact, a lot of research is headed towards this issue area. For example, a recent study published in 2022 in the Journal of Review of Accounting Studies noted that using Artificial Intelligence reduces the likelihood of accounting restatements and decreased audit fees at audit firms after 4 years.[1]

An Editorial published in the Journal of Emerging Technologies in Accounting notes that "Robotic Process Automation (RPA) has the potential to disrupt the traditional audit model. With its capability to automate rules-based tasks that are repetitive and manual, RPA is expected to repurpose the role of the auditor by replacing perfunctory tasks and emphasizing higher order thinking skills that will eventually lead to enhanced audit quality".2

A recent research article titled "How Blockchain Innovation could affect the Audit Profession: A Qualitative Study" published in 2022 in Journal of Innovation Economics and Management notes that "the Blockchain, through the implementation of a continuous audit process, the performance of audit tests on all company's data, and the securing of transactions by the various stakeholders, could significantly improve audit quality".[3]

In addition to research, several organizations released guidance, standards and frameworks to guide the implementation of emerging technologies. For example, the National Institute of Standards & Technology, which is a US Government Agency that promotes innovation and publishes guidance and standards is actively working towards establishing a NIST AI Resource Center. NIST has published an initial draft of AI Risk Management Framework in March 2022, which can be voluntarily used in addressing risks in the design, development, use, and evaluation of AI products, services, and systems.[4]

The United States Government Accountability Office has also published an AI Accountability Framework, which provides a comprehensive and practicable guidance on reviewing AI implementation with focus on accountability and responsible use of AI.[5]

The International Audit and Assurance Standards Board (IAASB), an independent body that sets standards for auditing, has recently published a series of market scan report about emerging technologies.

IAASB, in its market scan report published on Artificial Intelligence notes that AI is one of the most significant and potentially disruptive technology in auditing and assurance. The report considers Robotics, machine learning, computer vision, natural language processing, speech and expert systems as branches of Artificial Intelligence. The report also notes many use cases of AI for auditing and assurance. Some of these are listed below:

- Audit Planning
- Understanding entity systems and risks
- Substantive procedures and
- Conclusion procedures

In brief, we can note that IAASB considers that AI has use cases across all phases of Audit Cycle.[6]

The Institute of Internal Auditors also published an Artificial Intelligence Auditing Framework and has also been publishing exploratory material on other advanced technologies like data analytics, cybersecurity, data visualization etc. It has also recently published a Report titled "Future Ready: Upskilling Today for the Profession of Tomorrow".

The IIA's Global Perspectives and Insights: 5G and the 4th Industrial Revolution, looks at key issues that are bound to arise once 5G is a reality. From implementation challenges, legal issues, and regulatory tests to disruptive technologies, data management, and cybersecurity concerns, the report seeks to prepare organizations for the potential impacts of 5G so they can proactively address the issues.[7]

ISACA (Information Systems Audit and Control Association), the body that is one of the leaders in information systems auditing guidance and administers IS Auditing certification, CISA, has also been closely following the developments related to emerging technologies. It has published a whitepaper titled "Auditing Artificial Intelligence" that provides guidance from an auditing practitioners' point of view.[8]

Apart from this and understanding the importance of emerging technologies, ISACA does now offer Certificates for Blockchain Fundamentals, Artificial Intelligence Fundamentals, IoT Fundamentals and Cloud Fundamentals.

The objective of this Environment Scan undertaken by WGISTA was to understand the various emerging and advanced technologies that may impact the auditing profession and that status of their exploration and implementation at SAIs. The study focuses on technologies like Artificial Intelligence, Machine Learning, Blockchain, Data Analytics, Quantum Computing and 5G etc.

We used three research tools listed below to complete our study:

- Literature Review
- Environment Scanning Survey of SAIs
- Expert Interviews

The research study provides a brief introduction of emerging technologies, followed by the literature review and analysis of the environmental scanning survey. We also added a summary of our discussions and interviews with experts. At the end, we included a discussion to aggregate the results.

We would also like to express our gratitude to the following esteemed professionals for their response to our interview requests and providing us with an informed academic and professional insight on the issues of emerging technologies:

- Dr. Emin Gun Sirer, Associate Professor and Co-Director, Initiative for Cryptocurrencies and Smart Contracts, Cornell University, USA
- Dr. Daniel Ho, Associate Director, Stanford Institute for Human-Centered Artificial Intelligence, Stanford University, USA
- Dr. Khem Emrith, Head of Industrial Engagement, Mohammed bin Zayed University of Artificial Intelligence, UAE
- Dr. Abdelrahman AlMahmoud, Principal Big Data and Analytics Researcher, Technology Innovation Institute, UAE

- Mr. Musab AlHammadi, Project Manager, Artificial Intelligence, Digital Economy and Remote Work Applications Office (UAE)

Defining Emerging Technologies

We start with providing definitions of important emerging technologies and a general understanding of their meaning. Please note that we provide more technical, detailed and academic definitions/ explanations resulting from Literature Review, later in this report.

Artificial Intelligence

Artificial intelligence (AI) is the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings. The term is frequently applied to developing systems endowed with the intellectual processes characteristic of humans, such as the ability to **reason**, discover **meaning**, **generalize**, or **learn** from experience.[9]

While computers can be programmed to carry out laborious and complex tasks, only recently the advances in the processing speeds and memory of computers has made it possible to use these for more intelligent purposes.

Still, computers cannot match the flexibility of human intelligence, but with ever-increasing processing powers, the artificial intelligence has evolved into a serious field with already practical applications like medical diagnosis, voice & handwriting recognition and natural language processing etc.

Machine Learning (ML)

Encyclopedia Britannica defines machine learning as a "discipline concerned with the implementation of computer software that can learn autonomously".[10]

Machine learning is a field of study that focuses on developing methods of data-driven learning or methods that 'learn' in order to improve performance on some set of tasks. This is seen as a part of artificial intelligence.

In machine learning, algorithms build a model based on sample data, (also known as training data,) to make predictions or decisions without being explicitly programmed to do so. Machine learning algorithms are used in a plethora of applications where it would be difficult or improbable to develop conventional algorithms to perform the needed tasks.

Blockchain

Blockchain is a "shared, immutable ledger that facilitates the process of recording transactions and tracking assets in a business network. An asset can be tangible (a house, car, cash or land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a Blockchain network, reducing risk, and cutting costs for all involved".[11]

Quantum Computing

Encyclopedia Britannica defines Quantum Computing as an "experimental method of computing that makes use of quantum-mechanical phenomena. It incorporates quantum theory and the uncertainty principle. Quantum computers would allow a bit to store a value of 0 and 1 simultaneously. They could pursue multiple lines of inquiry simultaneously, with the final output dependent on the interference pattern generated by the various calculations.[12]

Quantum computing store information as Qubits which is different from the traditional 0s and 1s. This allowed the stored information to be treated in a multidimensional way at the same time, allowing the possibilities of computing exponentially.

Quantum computers are extremely fast. For example, Quantum Computer of Google named Sycamore performed a complex calculation in 200 seconds that would take even a supercomputer from IBM to do the same calculation in 2.5 days.[13]

5G

5G is the fifth generation of cellular technology. It is designed to increase speed, reduce latency, and improve flexibility of wireless services. 5G technology has a theoretical peak speed of 20 Gbps, while the peak speed of 4G is only 1 Gbps.

5G also promises lower latency, which can improve the performance of business applications as well as other digital experiences (such as online gaming, videoconferencing, and self-driving cars).[14]

Robotic Process Automation

Robotic process automation (RPA) refers to software that can be easily programmed to do basic, repetitive tasks across applications. RPA creates and deploys a software robot with the ability to launch and operate other software.[15]

RPA is a technology that is used to build software robots that emulate human actions. They can understand, like humans, what is on screen, launch and navigate applications and perform the right keystrokes. They can also extract data and perform the programmed actions. The technology can be a significant time saver, as it performs the mundane and laborious work with a lot more speed with higher consistency.

Literature Review - Emerging Technologies and Auditing

Emerging technologies such as artificial intelligence (AI), robotic process automation (RPA), 5G, Blockchain, and quantum computing have the ability to deliver new capabilities, create efficiencies, and transform how governments execute missions across many sectors.

However, there are risks and challenges associated with implementing these technologies in the public sector, either due to their inherent characteristics and opaque nature, or the lack of regulations and standards or a deficit in the skills and expertise necessary to understand them. These issues may also limit third-party assessments and audits of these technologies.

To better understand these issues, we conducted a review of literature, which included reports, journal articles, and trade publications, government documents related the:

(1) policies and regulations for the technologies;

(2) sectors and stakeholders involved in the technology;

(3) workforce skillsets necessary to audit and implement the technology;

(4) auditability of the technology; and

(5) risks and challenges in deploying the technology in the public sector.

We have included our methodology at the end of this document. See a summary of the literature we reviewed in the "***Summary of Review of Literature"*** section below.

Background

Emerging Technology Definitions

According to the literature we reviewed, the following definitions were noted:

Artificial intelligence. The term AI has a range of meanings in the scientific literature. One government defines AI as: a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations or decisions influencing real or virtual environments. Artificial intelligence systems use machine and human-based inputs to:

(A) perceive real and virtual environments;

(B) abstract such perceptions into models through analysis in an automated manner; and

(C) use model inference to formulate options for information or action.[16]

This definition has not yet been widely adopted within the data science community.

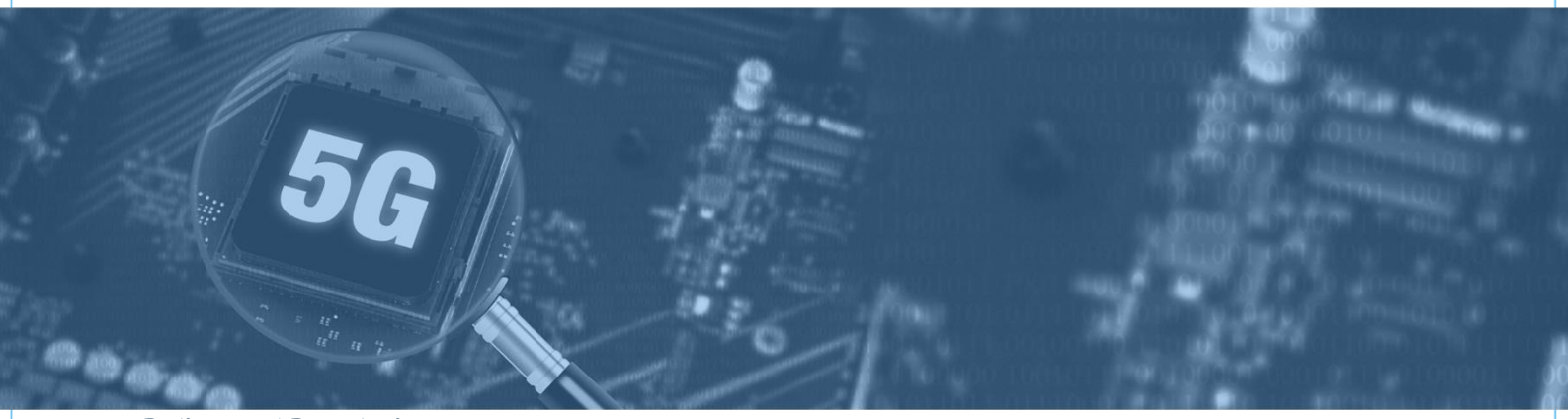
Robotic Process Automation. Robotics process automation (RPA) is the implementation of automation software to perform high-volume, labor-intensive, repeatable tasks. RPA can be deployed to increase quality, reduce human error, increase compliance, strengthen control environments, and offer new services.[17]

RPA has similarities with the first wave of AI, as characterized by the Defense Advanced Research Projects Agency, which is defined as handcrafted knowledge and has no learning capability and relies on an expert or rules-based system that produces outputs consistent with its programming.[18]

5G. 5G refers to a fifth-generation wireless network, which has the potential to greatly improve mobile communication. For instance, 5G may lead to faster and more responsive signals from cell phones and other devices, deliver more reliable connections and higher energy efficiency; to accommodate more devices, and faster network response times (also known as low latency).[19]

Blockchain Technology. Distributed ledger technologies such as Blockchain allows users to carry out digital transactions without the need for a centralized authority. Multiple participants in a computer network (individuals, businesses, etc.) share and synchronize copies of the ledger. New transactions are added in a manner that is cryptographically secured, permanent, and visible to all participants in near real time.[20]

Quantum Computing. Quantum technologies build on the study of the smallest particles of energy and manner to collect, generate, and process information in ways not achievable with existing technologies. Quantum computing uses superposition and entanglement to process data in unique and potentially more effective ways.[21]



Policy and Regulations

Summary

Based on our review of the literature, we identified several implications in the use of these emerging technologies and policy considerations needed for the development, implementation, and adoption of them. Specifically, the literature showed that while steps have been taken, standards are needed to ensure that these technologies are operating safely and securely. It also showed that incentives are lacking for developing and implementing these technologies in the public sector.

Artificial intelligence. Governments have introduced policies to better regulate and incentivize the use of AI systems within the public sector. For example, the Canadian government requires its departments to use automated decision systems to reduce risks and enable more efficient, accurate, consistent, and interpretable decisions.[22] Similarly, the Singaporean government developed guidance on the responsible use of AI in four key areas: (1) internal governance structures and measures, (2) determining the AI decision-making model, (3) operations management, and (4) stakeholder communications.[23] However, AI policies and regulations may not incentivize innovation in certain sectors. For example, AI applications in healthcare are not incentivized to promote high-quality data sharing and ensuring the protection of patient data.[24] Finally, countries have also introduced legislation and resolutions to ban the use of AI systems, such as facial recognition technology for police and judicial authorities due to the possibility of false positive recommendations and outputs from AI systems.[25]

Robotic process automation. There is a lack of guidance on how to implement RPA, which may lead to potential high failure rates of RPA bots.[26] Governments have been quickly adopting RPA to achieve efficiencies, and reduce low-value workload. The U.S. General Services Administration estimates that current U.S. government RPA programs are

achieving five hours of workload elimination per employee.[27] In 2019, the European Parliament adopted a resolution recognizing the use of RPA and its impact on improving public processes.[28]

5G. Policies and regulations for 5G wireless networks do not ensure equitable access, nor do they prioritize standardized practices in managing 5G networks. Privacy, cybersecurity and the protection of critical infrastructure have become the main focal points for policy discussions on 5G.[29] For example, 5G provides more enhanced data compared to existing technology, such as more precise location data. In addition, the literature we reviewed identified the need for reduced restrictions, particularly for local jurisdictions, on the construction of 5G infrastructure. For example, a city in the U.S. charged a company $60,000 in application fees to install 16 small wireless sites, only to reject the application and charge the company for $350,000 in attorney's fees.[30] Finally, standardized practices in managing 5G networks based on technical aspects are needed to establish universally accepted norms and prevent dependency on a single country or entity's approach.

Blockchain technology. Governments are focused primarily on regulating cryptocurrency and related aspects of Blockchain technology, which may adversely affect the adoption of Blockchain technology for other uses. Despite other applications of Blockchain, such as in accounting and auditing to review recorded transactions or to provide visibility in supply chain management, regulations are focused on cryptocurrency and anti-money laundering efforts, as these particular uses of Blockchain may facilitate illegal activities. There is also uncertainty in how governments apply such regulations. For example, there is no international standard for cryptocurrency and Blockchain activity taxes, with some countries treating cryptocurrency taxation as capital gains or income tax, while others treat it as property.[31] [32] [33]

Quantum computing. Quantum computing technology is not fully mature—and is not estimated to be so for 20 years with little to no implementation of this technology in the public sector. According to the literature we reviewed, policy considerations for quantum computing are focused on the need to establish and promote a workforce to further develop quantum technologies and to address cybersecurity concerns through use of quantum computing.[34] For example, a full-scale quantum computer has the potential to break standard encryption technologies, creating a major information security risk.

Sectors

Summary

Based on our analysis of the literature, we identified numerous sectors that are impacted by these emerging technologies. The sectors include those developing the technology as well as end users and downstream entities that support or enhance these technologies.

Artificial intelligence.

Health care: AI technologies show promise for improving healthcare by predicting health trajectories, recommending treatment, and automating administrative tasks.[3]

Autonomous vehicles: AI technologies enable automated cars and trucks to assess situations, make plans, and execute vehicle control decisions.[4]

Financial markets: AI technologies within financial service firms in the banking, securities, and insurance industries can support functions such as customer service operations (e.g. automating call center functions using chatbots), client wealth management, consumer risk profiling, and internal controls. RPA tools can support auditing functions, such as data entry, and reconciliation of financial and accounting data between sources.[5]

Criminal justice: Several early-stage applications of AI in criminal justice include predicting where crime is likely to occur, assisting in the identification of suspects, and assessing the risk for recidivism.[6]

Cybersecurity: AI can help cybersecurity professionals reduce the time and effort to identify and patch vulnerabilities, detect attacks, and defend against active attacks.[35]

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[3]GAO. (2018, March 28). Artifical Intelligence: Emerging Opportunities, Challenges, and Implications, GAO-18-142SP. D.C., Washington.

[4]Ibid.

[5]Ibid.

[6]Ibid.

Robotic process automation.

Accounting and auditing: RPA can be used to conduct transaction reviews, incorporate automated controls, ensure compliance with standard operating procedures, and conduct risk assessments and surveying.[7]

Business administration: Businesses can incorporate RPA to achieve efficiencies in finance, human resources, IT services, procurement, and administrative services.[8]

Data analytics: RPA functions to support data analytics include automated data reporting, data gathering and cleansing, data mining, and performance monitoring.[9]

5G.

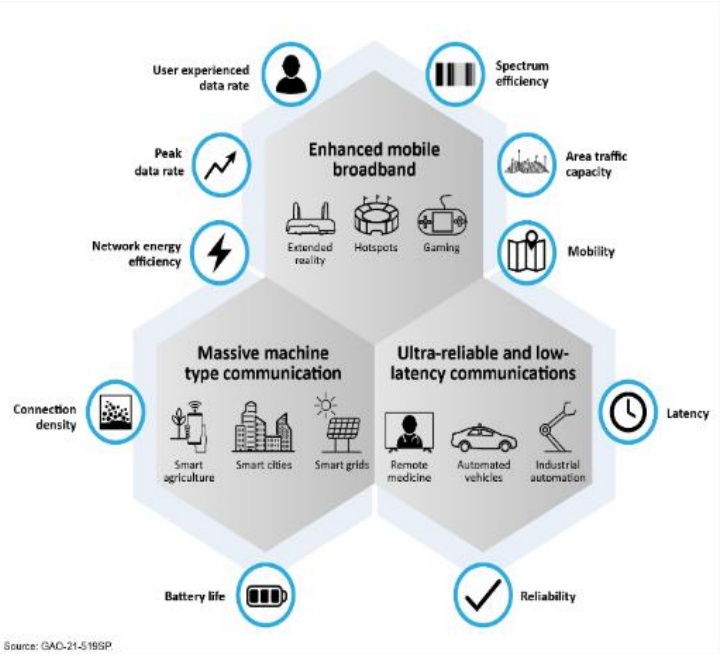
Urban development: 5G will influence the development of network-connected cities through the use of sensors, cameras, and other technologies to improve traffic flow, public safety, and energy efficiency.[10]

Manufacturing: In addition to manufacturing of Internet of Things devices, 5G wireless networks can modernize manufacturing processes through improved communication between operators and equipment.[11]

Multimedia entertainment: 5G wireless networks can enhance mobile broadband connectivity and improve the user experience with hand-held devices, virtual reality, and video streaming. It is also expected to enable new applications, such as 3D video streaming and extended reality.[12]

Telecommunications: 5G wireless networks are currently being deployed in many areas. Deployment might require investments in various areas to improve network performance as well as physical infrastructure.[36]

Figure 1: Sectors Impacted by 5G



[7]Federal RPA Community of Practice. (2020, January 17). RPA Program Playbook. D.C., Washington.

[8]Ibid.

[9]Ibid.

[10]GAO. (2020, March 27). Science & Tech Spotlight: 5G Wireless, GAO-20-412SP. D.C., Washington.

[11]Ibid.

[12]Ibid.

Blockchain technology.

Financial services and accounting: One of the best-known use cases of Blockchain technology is cryptocurrency, which carries out digital transactions without a central authority.[37] The nature of Blockchain, where transactions are immutable, timestamped, recorded in real-time and encrypted, makes it ideal for use in accounting.[38]

Energy: Excessive energy use or computing power is often needed to generate new units of cryptocurrency.[39] For example, cryptocurrency using "proof-of-work" consensus tools (also known as "mining") require large amounts of computing power and energy to generate new units of currency.

Supply chain management: Within the supply chain industry, Blockchain is considered an emerging technology capable of tracking products from their origin as basic raw materials to final customer delivery, mitigating the risk of counterfeit or illegal goods and products40

Other sectors: impacted by Blockchain include telecommunications, and healthcare.[13]

Quantum computing.

While not fully mature, quantum computers will have the ability to speed up applications such as machine learning, chemistry modeling, and cryptography.[41]

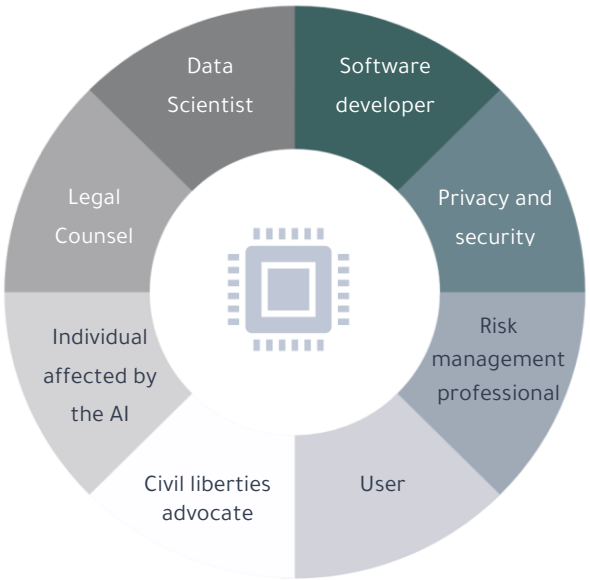
Stakeholders

Summary

Based on our analysis of the literature, we identified a range of stakeholders that can provide technical, legal, and other specialized fields of expertise (e.g. privacy, energy, risk management, etc.) to ensure that all factors are considered in developing these technologies.

Artificial intelligence. AI involves a range of stakeholders, including software developers, privacy and security experts, risk management personnel, end users, individuals affected by the AI system, civil liberties advocates, legal counsel, and data scientists. See the figure 2 below for the community of stakeholders involved in the development of AI. Each stakeholder plays a role in ensuring that any ethical, legal, economic, or social concerns raised by the AI system are identified, assessed, and appropriately mitigated.[42]

Figure 2. Example of the Community of Stakeholders Engaged in AI Development



For example, AI systems could perpetuate historical biases, such as underrepresentation of groups based on race, socioeconomic status, or gender. The community of stakeholders should provide input on potential societal concerns

[13]GAO. (2019, September 16). Science & Tech Spotlight: Blockchain & Distributed Ledger Technologies, GAO-19-704SP. D.C., Washington.

during design and development to ensure the AI system is appropriate for the use case and representative of the intended population. Stakeholder input can help to address these unintended consequences.

Robotic process automation. Similar to artificial intelligence, a range of stakeholders are involved in the development and use of RPA, including those focused on developing RPA capabilities and those impacted by the technology.

Given the increased use of RPA tools by the public sector and the magnitude of RPA transactions (e.g. continuous, rapid evaluations based on pre-specified rules), civil liberties advocates, legal counsel, and other privacy and security experts can provide insight to ensure that ethical, legal, and social concerns can be identified and mitigated.

5G. The stakeholders involved in developing and overseeing 5G include hardware developers of 5G wireless networks and technology developers incorporating 5G into devices, safety and security experts, advocacy groups, regulators, and legal counsel.

Each stakeholder provides expertise on developing 5G wireless networks in accordance with standards and regulations. For example, privacy and security experts provide recommendations on exposure limits for radio frequency radiation associated with 5G networks.[43] Advocacy groups provide perspectives on ensuring equitable access to disenfranchised populations. Regulators assign, facilitate, and regulate available spectrums for usage across public and private entities and take steps to prevent the widening of the digital divide.[a] Legal counsel provide expertise on navigating laws and regulations at the national and local level. Together, these stakeholders ensure that developers of 5G wireless networks take into account other factors that may affect responsible and equitable deployment of these networks.

Blockchain technology. A number of stakeholders are involved in developing, using, and overseeing Blockchain technology, including software and hardware developers, accounting and cryptocurrency specialists, end users, and legal counsel. These stakeholders provide expertise on how Blockchain ledgers are designed to meet their stated objectives. For example, software and hardware developers design the architecture of the ledger and how transactions will be recorded. Financial, accounting and cryptocurrency specialists can provide guidance on auditing Blockchain ledgers and the regulating cryptocurrency. Input from these stakeholders can help to address the issues faced by Blockchain technology, such as its high-energy requirements for operation and its use in facilitating illegal activities.[44]

Quantum Computing. The stakeholders involved in quantum computing include multidisciplinary workforces with training in quantum physics, engineering, mathematics, and computer science. Since quantum computing is still a nascent technology, stakeholders with scientific expertise can conduct further research and mature the technology for a wide array of applications, including advancing machine learning methods and processing complex calculations. 45

In addition, sociologists and anthropologists can assess the role quantum technologies play in social and cultural interactions. [46]

[a] Spectrum refers to **the radio frequencies allocated to the mobile industry and other sectors for communication over the airwaves.**

Workforce Skillsets

Summary

Based on our analysis of the literature, it showed that there is a deficit in skills, expertise and competencies in the public sector to manage, operate and oversee the implementation of these emerging technologies. In addition, auditors need training opportunities to ensure their continuous professional development to strengthen their skills and expertise to audit these technologies. For example, the PursuIT journal (India) highlighted the need for auditors to understand certain technologies such as artificial intelligence and Blockchain technology.[47]

Artificial intelligence. Auditors should have an understanding of the different types of AI methods such as machine learning, deep learning, and other AI processes. In addition, auditors should have proficiency in data literacy to better understand how data are collected, evaluated for sufficiency, and utilized to train, test, and deploy AI systems.

Robotic process automation. Similar to auditor needs for artificial intelligence, they should be able to understand how RPAs are programmed, as RPA relies on a high volume of consistent transactions that follow pre-specified steps.[48] However, unlike artificial intelligence, there are less inherent risks posed by RPA as they are limited in capability based on how they have been programmed.[49]

Auditors may also employ RPA to make better use of scarce resources, increase efficiency in audits, and reduce costs. For example, RPA tools can be used to automate text-heavy documents or automation of other internal audit tasks.[50] In addition, while an employee might have the bandwidth to audit a 10 percent sample of transactions, an RPA can audit the entire data set and send non-compliant records for adjudication.

5G. Auditors need the skills to understand how 5G wireless networks operate, including how spectrums are allocated and distributed for public and private use. Auditors also need to understand how to deploy supporting infrastructure for 5G, including the installation of fiber optic cables or small cells.

Blockchain technology. Auditors are expected to focus more on complex analysis, such as systemic evaluation, risk assessment, predictive audits, and fraud detection.[51] Auditors will need an understanding of Blockchain technology to determine practical applications, business uses and assess the potential of fraudulent transactions.

Quantum computing. Auditors need an understanding of both quantum computing and the context in which the technology is used. Quantum technology has applications in improving measurements, enabling secure communications, and solving complex problems.

Auditability of the Technology

Summary

Based on our analysis of the literature, some of these emerging technologies have inherent characteristics that can support audits. For example, Blockchain technology provides transparency of all record-keeping transactions that auditors can review.[14] Auditors can develop best practices to understand the technology, such as specific audit approaches, customized question sets for each of the technologies, and procedures that can ensure access to conduct technology audits. In addition, skilled auditors can employ these technologies to enhance audits. For example, deep learning methods may be applied to collect and assess evidence with greater speed and efficiency.

Artificial intelligence. Accountability of AI poses unique challenges for independent assessments and audits because their inputs and operations are not visible to the user. However, in recent years, governments and other organizations have developed governance and auditing frameworks, in part to address the technical and societal issues in using AI in the public sector. These frameworks—such as GAO's AI Accountability Framework—provide key information such as audit approaches (e.g. question sets and methodologies) and leading practices to review governance, data, performance, and monitoring of AI systems.[52] [53] [54] Auditing machine learning algorithms identifies potential audit tests and risk assessments that auditors can conduct to assess the data, model development, and evaluation of AI systems.

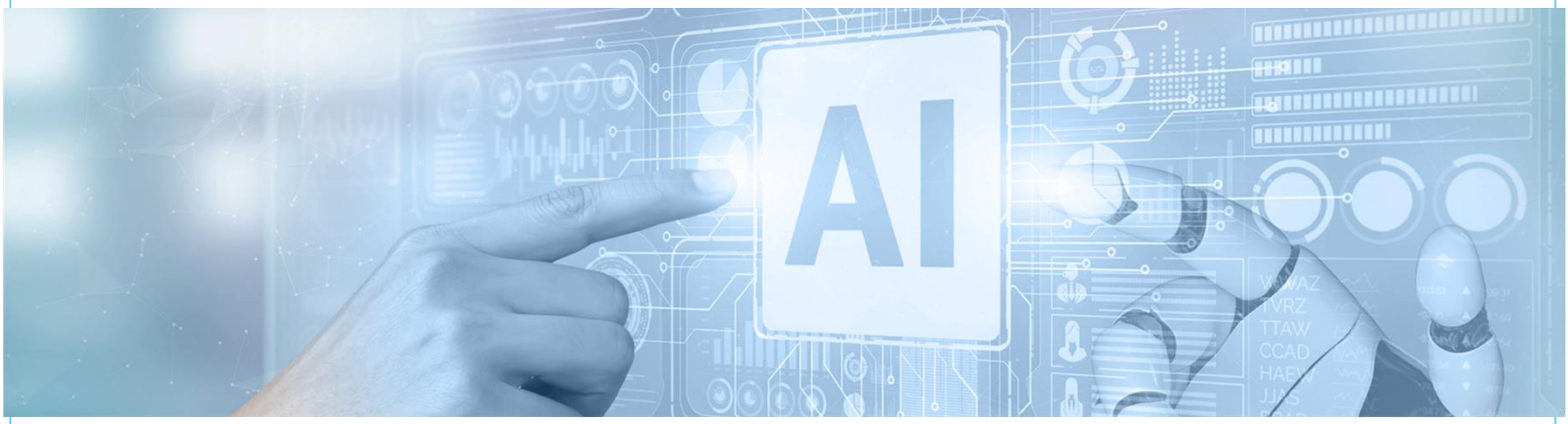
[14]GAO. (2022, March 23). Blockchain: Emerging Technology Offers Benefits for Some Applications but Faces Challenges, GAO-22-104625. D.C., Washington.

Robotic process automation. RPA shares some similarities with artificial intelligence, as an RPA's access to data, systems, and files, along with their magnitude of throughput can make them a controls challenge. The Federal RPA Community of Practice's executive guide assessing compliance and control risks for RPA states that the GAO's Standards for Internal Control in the Federal Government sets the standards for an effective internal control system and can be used as a basis to address implementation risks for RPA.[55] In addition, the guide provides additional considerations to assess the unique characteristics of RPA along the key control objectives of auditability, security, compliance and performance. For example, auditors can review design plans, systems interactions, data privacy standards, development and coding approaches, and credentialing strategies.

5G. Leading practices could increase auditability of 5G wireless networks. For example, those employing such networks should identify specific and measurable performance goals to show progress towards broad strategic goals.[56] While the auditability of 5G remains underdeveloped, the Australian Media and Communications Authority has carried out a few audits on 5G stations to ensure compliance with electromagnetic levels and deployment codes and has published these audits.[57]

Blockchain technology. Blockchain technology has inherent characteristics that can facilitate audits such as the transparency of transactions and its better data quality and reliability compared to traditional systems. However, due to the permanence of Blockchain transactions, it may be difficult to correct errors on the ledger.[58] In addition, despite the inherently transparent nature of Blockchain, those with a majority of the computing power can make changes to the blocks and conduct fraudulent transactions. Finally, there is a lack of clear guidance on what constitutes sufficient and appropriate audit evidence for other uses of Blockchain technology.[59]

Quantum computing. Despite the maturity level and adoption of quantum computing in the public sector, the literature we reviewed noted opportunities to conduct audits of quantum computing. Notably, auditors can leverage existing frameworks used to assess artificial intelligence to evaluate quantum computing.[60] In addition, auditors can also assess the infrastructure necessary to support quantum computing, such as refrigeration techniques that ensure insulation of quantum computing technologies from ambient environments.[61]



Risks and Challenges in the Public Sector

Summary

Based on our analysis of the literature, we identified several risks and challenges in employing these technologies in the public sector. Specifically, there are privacy, security and safety concerns, particularly for end users or impacted individuals. In addition, these technologies are constantly evolving or in early stages of implementation within the public sector. Finally, public sector entities that procure such technologies may not have access to the underlying code, system, or program due to intellectual property concerns.

Artificial intelligence. Privacy, security and safety concerns exist for both the data utilized for AI systems and the outputs of the AI systems. For example, facial recognition technology may not be as accurate for certain demographics such as females or people of color. In addition, individuals may be impacted by the decisions made by AI systems without any adjudication process.[62]

Robotic process automation. While RPA can gain efficiencies through scaling and efficiency, these benefits also pose unique risks. For example, the impact of flawed logic or processing errors can create significant workloads to investigate, evaluate, and rework. Rogue automation builders can operate outside of established norms, creating privacy, security, and operational risks for the entire organization.[63] RPA has unique risks that can affect its ability to operate in a safe and secure manner. In addition, current ongoing challenges in adopting RPA in the public sector

include approving individual RPA capabilities across government agencies and the lack of consistent policies to transmit data or recertifying RPA applications that interact with classified or restricted data.

5G. 5G networks present concerns over cybersecurity, privacy, electromagnetic radiation, and a worsening of the digital divide.[64] In addition, countries with private, domestic development of 5G will have more access to a robust infrastructure to deploy 5G wireless networks.

Blockchain technology. Challenges exist related to the scalability of the technology, cybersecurity, implementation costs, computing power requirements, and related environmental concerns associated with Blockchain and its high-energy use. According to our literature review, the reliability of Blockchain technology as a financial reporting tool may be vulnerable to cyberattacks, as groups with majority control of the network's computing power may modify a ledger or transaction history. [65]

Quantum computing. According to the literature we reviewed, development and use of quantum computing is not as widely used in the public sector.[66] Thus, little is known about challenges in its public-sector applications. In addition, quantum computing and technologies depend heavily on the development of new capabilities, some of which are currently in the conceptual phase and have yet to fully mature. For example, quantum sensors need to surpass current operating limits to be fully functional.

Methodology

Our literature review comprised of reports, journal articles, trade publications related to accountability, governance, equity, assessments of AI & 5G, Blockchain technology, and quantum computing. We reviewed various sources, including

(1) literature identified by Supreme Audit Institutions from a survey conducted by the Working Group on the Impact of Science and Technology on Auditing (WGISTA);

(2) Publications identified during a formal literature review, aided by a GAO research librarian and;

(3) Publications identified in literature searches from prior GAO work on these emerging technologies.

Our literature review included a search for peer-reviewed articles, government reports, and trade publications, among other sources, in databases such as Scopus, the Institute of Electrical and Electronics Engineers (IEEE), and ProQuest's science collections. We limited our results to publications from January 1, 2015, to fall 2021 which was when we conducted our search. As a result, we identified 49 publications for in-depth review of the practices related to governance and accountability these emerging technologies. In addition to the literature review, we also selected and reviewed 14 publications from a list of responses provided by the WGISTA survey. In all, we reviewed a total of 63 publications from our literature review and recommended literature. As part of our research, we considered existing frameworks and guides related to governance and auditing, including publications by foreign governments and the U.S. government. For a list of all the publications noted in the report, see the bibliography below.

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Summary of Review of Literature

In this section, we provide a summary of the literature we reviewed related to the (1) policies and regulations for the technologies; (2) sectors and stakeholders involved in the technology; (3) workforce skillsets necessary to audit and implement the technology; (4) auditability of the technology; and (5) risks and challenges in deploying the technology in the public sector.

Table 1. Literature Review Findings for the Auditability of Emerging Technologies

	Artificial intelligence (AI)	Robotic process automation	5G networks	Blockchain technology	Quantum computing
Public Sector Adoption	Deployment	Deployment	Deployment	Deployment	Design
Policies and Regulations  Source: dmitriy-orlovskiy/stock.adobe.com	Governments have introduced policies to better regulate and incentivize the use of AI systems within the public sectors. Governments have also introduced legislation or resolution to ban the use of AI systems for certain use cases.	There is a lack of guidance on how to implement RPA, which may lead to potential high failure rates of RPA bots.	Policies and regulations for 5G wireless networks should focus on improving cybersecurity, privacy, ensuring equitable access, and prioritizing standardized practices in managing 5G networks.	Policies currently focus primarily on regulating cryptocurrency and related aspects of Blockchain technology, which may adversely affects the adoption of Blockchain technology.	Quantum computing technology is not fully mature—and is not estimated to be so for 20 years.
Sectors  Source: t-vector-icons/stock.adobe.com	Health care, autonomous vehicles, financial markets, criminal justice, cybersecurity, among others.	Accounting and auditing, Business administration, data analytics.	Health care sector (medical devices), urban development, manufacturing, Multimedia entertainment, automated vehicles, telecommunicatios.	Financial services and accounting, energy, supply chain management, telecommunications, healthcare.	Machine learning, chemistry modeling, and cryptography.

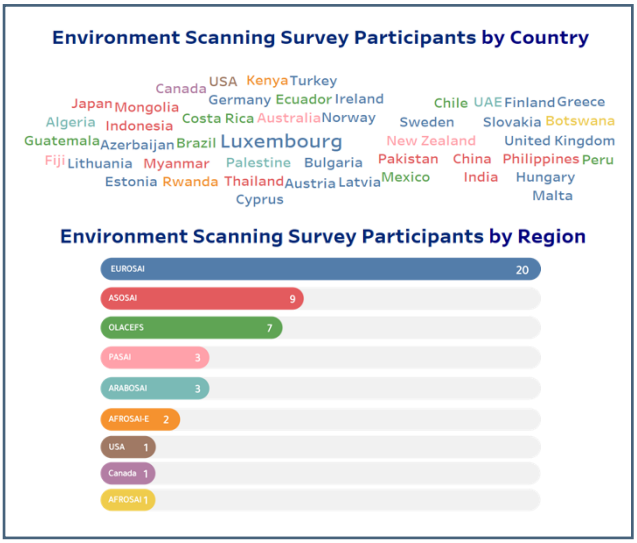
Results of Environment Scanning Survey

The discussion below shows how well are SAIs positioned with respect to overseeing, managing and implementing these emerging technologies.

To understand the maturity of SAIs related to these technologies; we developed a Survey Questionnaire that included technical as well as a few general questions. The questions were mostly descriptive in nature, which provided our respondents an opportunity to share as much information as they can.

There is no identifiable information related to any survey respondent (SAI) in this final report to ensure confidentiality. The analytical information from the Environment Scanning Questionnaire does not provide any identifiable information from the responses that can be linked to any of the SAIs which responded to our Questionnaire.

The Environment Scanning Questionnaire, which was circulated to all of the SAIs, was met with 47 responses.

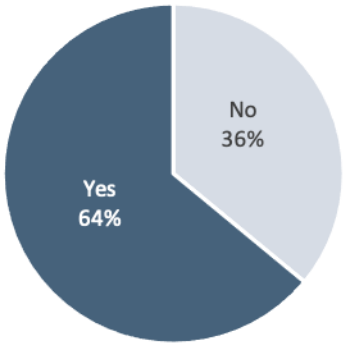


The above chart shows a territorial and graphical representation of our survey respondents: As shown in the chart, the questionnaire had wide representation in terms of INTOSAI regions. EUROSAI ranked first in terms of respondents, with 20 responses. This was followed by ASOSAI with 9 responses and OLACEFS was ranked third with 7 responses.

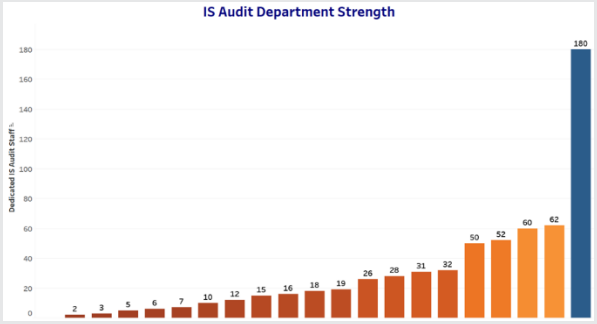
Do SAIs have a separate IS Audit Department?

When SAIs were asked if they have a separate Information Systems Audit Department in their structure, 64 percent said a separate department exists which caters to IS audits. The remainder 36 percent of the responses were in the negative. However, we understand that for SAIs with a smaller workforce, it may be challenging to establish a separate IS audit department.

Separate IS Audit Department



The Size of SAI IS Audit



Based on the responses when a SAI indicated an established IS Audit Department, its staff strength exists varied considerably by headcount across different SAIs.

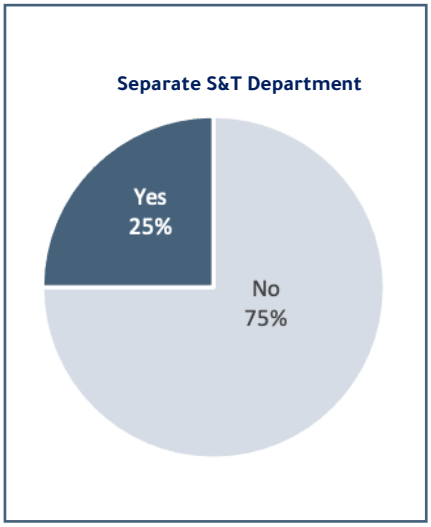
The smallest IS Audit Department is at 2 while the SAI with the biggest number of staff is 180.

SAIs with Separate Science & Technology (S&T) Departments

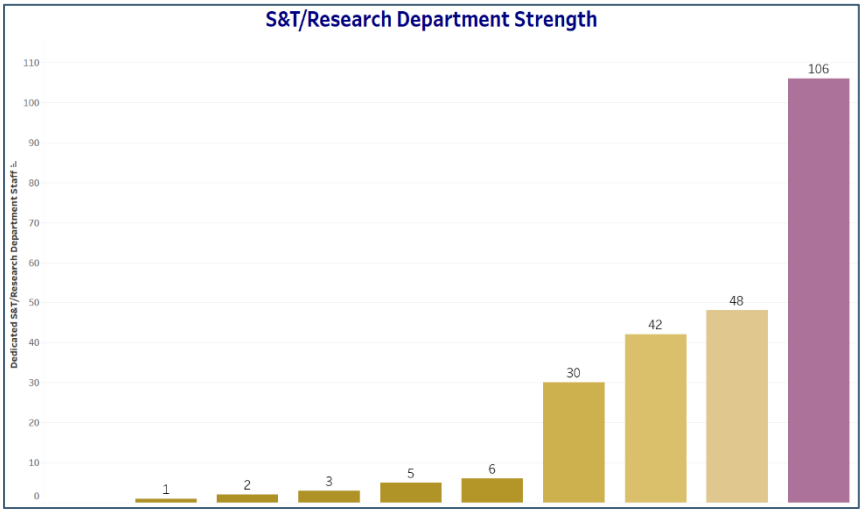
We also wanted to understand how SAIs are engaged in proactive research activities related to latest technologies. Therefore, we asked if Supreme Audit Institutions have a dedicated department or wing that is tasked with research about science and technology.

By looking at the right-hand graph, we can see that the majority (75 percent) said that they do not have such department, the remaining 25 percent replied in the affirmative.

This appears to be promising and indicates that SAIs have started to dedicate resources to studying the impact of science and technology on auditing.



Staff at SAI S&T Departments

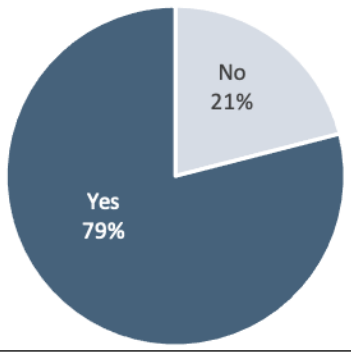


It was interesting to note one of the SAIs responded that they have one dedicated resource for Science and Technology. And the SAI with the highest number of dedicated staff in the Science and Technology Department reported a staff strength of 106. A few other SAIs also have reasonable staff strength dedicated for Science and Technology or research activities related to these.

Legal Mandate & Challenges Concerning Emerging Audit Technologies

Another area we wanted to understand was if the Supreme Audit Institutions had a legal mandate to audit the implementation of these emerging technologies. Almost 80 percent of the respondents stated that they have a reasonably clear mandate to audit emerging technologies. Our understanding is that when SAIs have a clear mandate for audit of Information Technology, the mandate for auditing emerging technologies is inherent in the parent mandate. As for the follow-up question relating to the legal mandate. Survey responses included:

- Yes - mandate exists or mandate exists but facing challenges
- No - explicit mandate, or explicit mandate but no challenges faced.



We also received responses which state that even though there is no such explicit mandate, SAIs do not face or foresee any challenges.

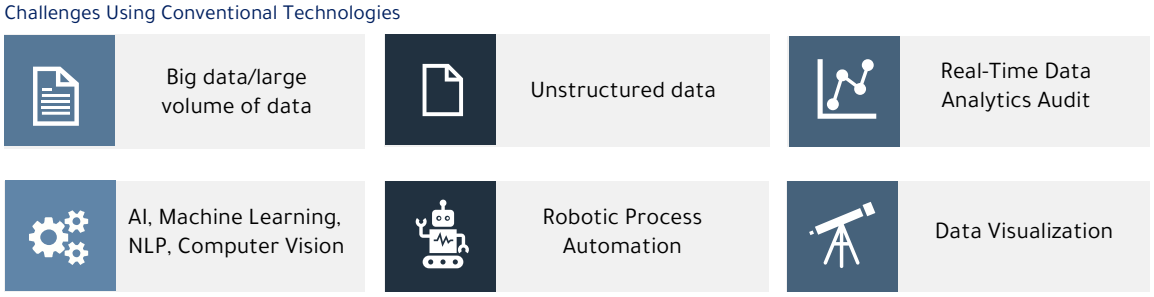
On the other hand, a few SAIs responded that though they have a mandate, they face challenges of access to electronic data.

Our overall conclusion based on the responses, is that SAIs do not foresee any mandate challenges after the mainstreaming of these emerging technologies.

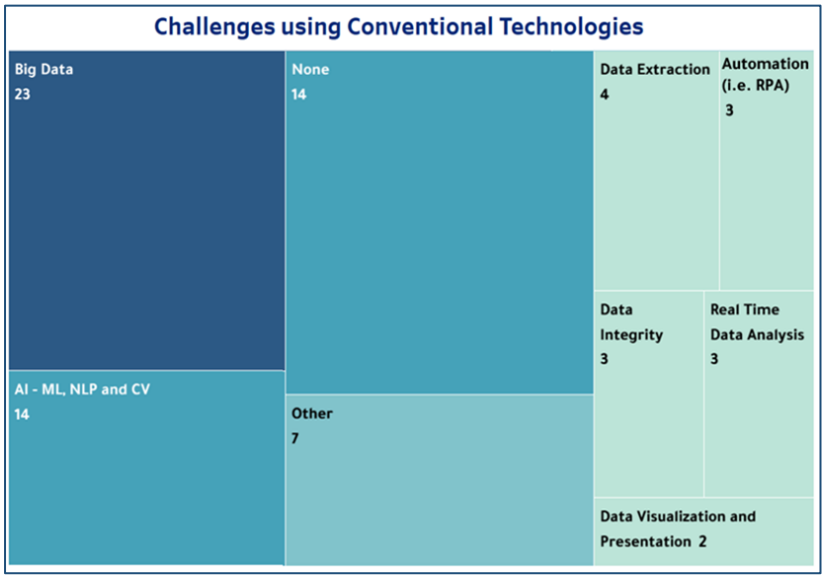
We also requested SAIs to identify the challenges they face, or might face that cannot be addressed by the conventional technologies that Supreme Audit Institutions use during the course of their audit. As you can see, SAIs responded that the challenges unaddressed by conventional technologies include:

- Big data/large volume of data
- Unstructured data - which includes voice data, scanned documents, visual data, video data etc.
- Artificial intelligence, Machine Learning, Natural Language Processing and Computer Vision
- Real-Time Data Analytics Audit
- Robotic Process Automation
- Data Visualization

All these advances in technology provide opportunities for improving auditing but conventional technologies cannot respond to these challenges and opportunities.



Challenges Using Conventional Technologies



This graphic provides information across a number of respondents. As you can see 23 responses considered big data a challenge, 14 responses considered AI, ML, NLP and CV as a challenge.

Meanwhile, 14 of the respondents indicated that there are no challenges related to using conventional technologies.

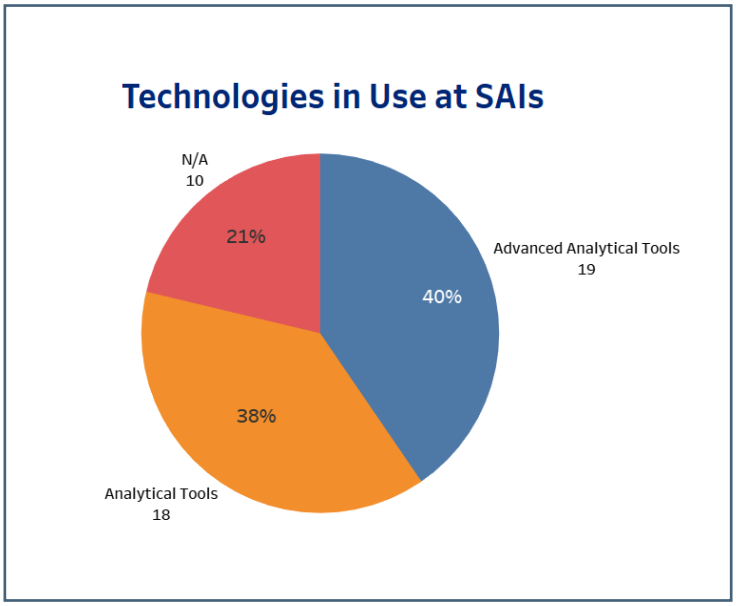
Other challenges identified by respondents included Data Extraction, Real Time Data Analytics and Data visualization etc.

Technologies In Use at SAIs

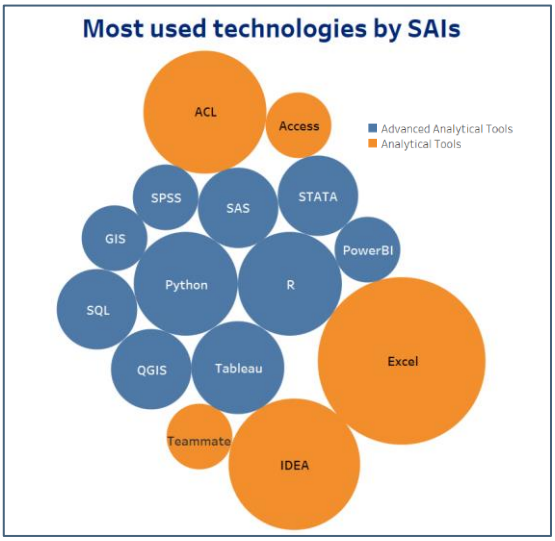
We also asked Supreme Audit Institutions to share with us their technology stacks to help us identify the most commonly used technologies.

At the same time, we also wanted to know about the tools and technologies used by SAIs to address challenges that are not adequately mitigated by conventional technologies.

We have grouped the technologies as Analytical Tools and Advanced Analytical Tools. The next chart will provide more details about these technologies in use at SAIs.



Most Used Technologies by SAIs



You can see that SAI prefer tools like Excel, IDEA, and ACL, as represented by larger bubbles in the below chart, which we consider as Analytical Tools (colored orange).

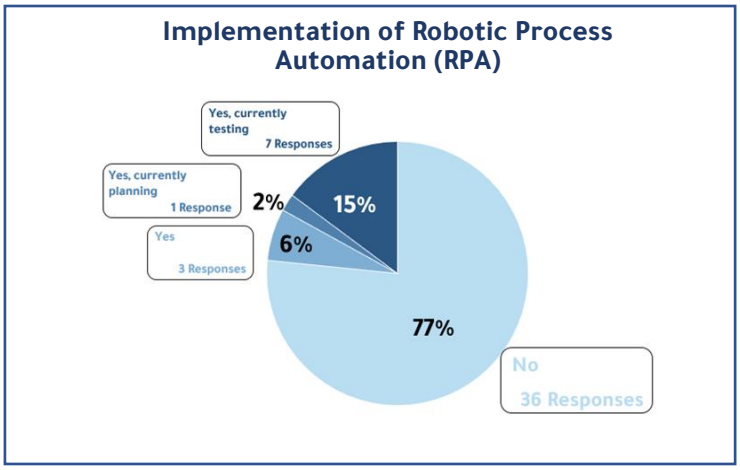
However, many SAIs are making full use of the advanced tools (colored blue) which are still not mainstreamed across SAIs but provide us with a window into the technologies that can help public sector auditors in their work.

Python and R appear to be very useful for SAIs while other SAIs are also making use of data visualization tools like Tableau and PowerBI to enhance the graphical presentation of their reports.

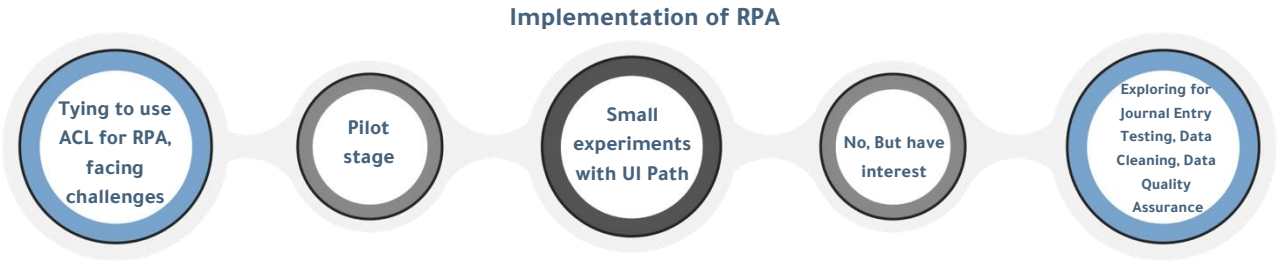
Most Used Technologies by SAIs

Robotic Process Automation is a technology that has the potential to save auditors from laborious work and can help by providing more time for questions of insight and analysis.

We asked SAIs if they were using RPA and the majority (almost 80 percent) replied in the negative. However, it is promising to note that a minority of SAIs is exploring this emerging technology proactively.

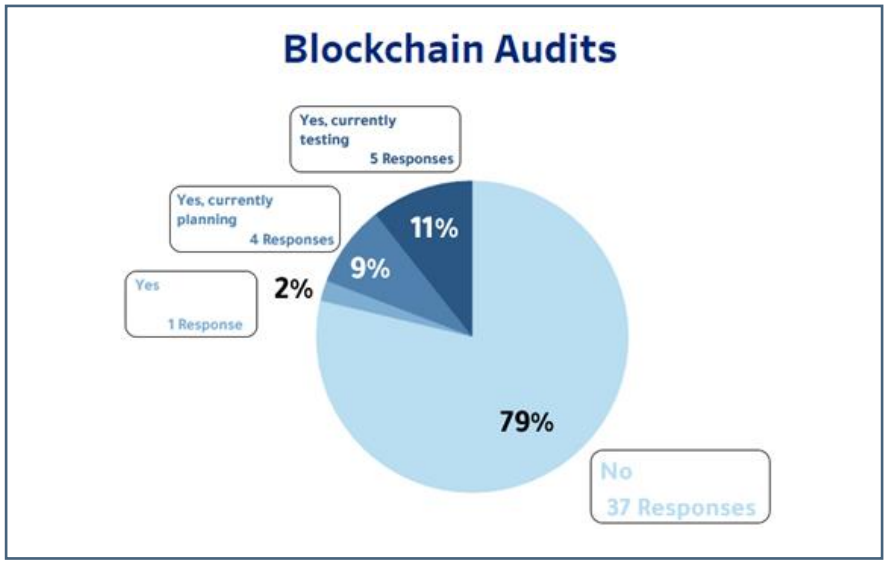


Implementation of RPA at SAIs



As you can see, this chart lists some of the useful responses we received on the implementation of RPA. But apparently this emerging technology is still at a very nascent stage at among SAIs. Responses include: pilot stage, trying ACL and UI path or researching use cases.

Blockchain Audits

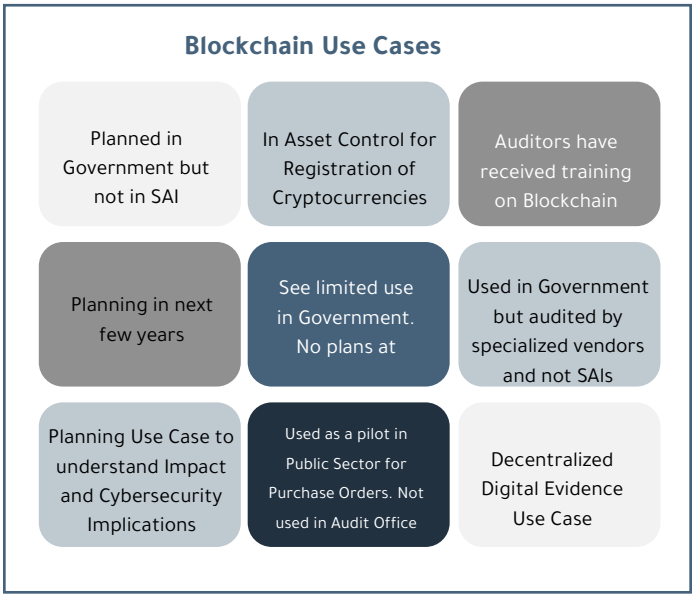


We asked Supreme Audit Institutions if they were using Blockchain in their audits. Since this is an emerging technology, most of the respondents indicated no, which was in line with our expectations. However, some of the SAIs are exploring Blockchain technology.

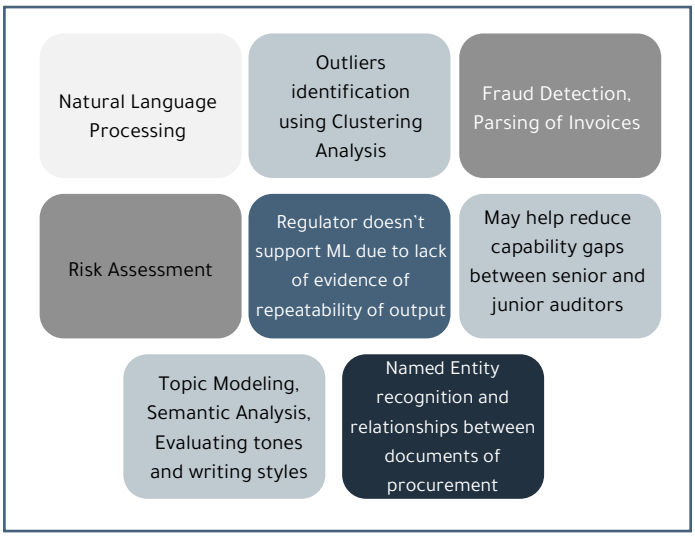
Blockchain Use Cases

This figure shows some of the useful responses we received that provide us more insights in the use cases for Blockchain that auditors are currently exploring.

Most of the responses indicate that even the SAIs that are exploring this technology are either at the planning stage or at the pilot study level. We can also see that one SAI has trained its auditors on Blockchain.



Application of ML at SAIs



Our next question was about the application of machine learning at Supreme Audit Institutions. While 47 percent of the responses indicate that they are not using machine learning/artificial intelligence (illustrated in the next section), quite a few are either using, testing or plan to use.

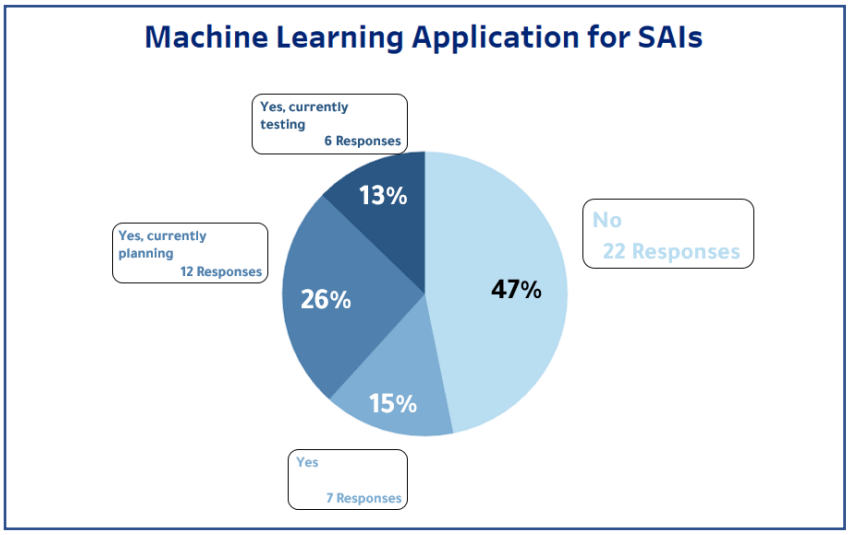
Supreme Audit Institutions also shared with us the use cases they are exploring with Machine learning. As you can see, these are some interesting potential uses of artificial intelligence or machine learning. Many of these areas are an inherent part of an auditor's work.

For example, outlier identification, risk assessment, parsing of invoices etc. are time consuming tasks.

Status of ML at SAIs

If we could leverage machines to help auditors with these tasks, they may have more time for intellectual work.

We also asked Supreme Audit Institutions if they have the capacity for cybersecurity audits or if they undertake it. 47 percent, about half of the responses said that they do not perform cybersecurity audits.



Cybersecurity at SAIs

Specialized Government Agency Responsible for these

Independent professionals hired for such audits

Auditee resist advanced cybersecurity audits

No need for advanced audits because of obvious/elementary mistakes we find

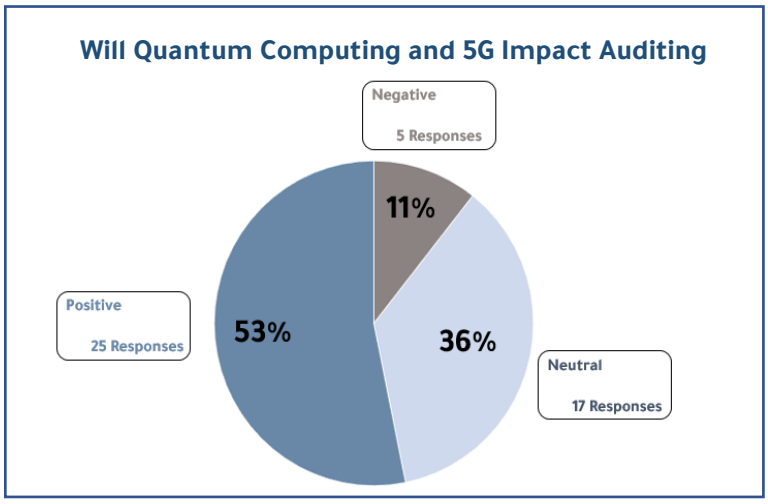
External agency does that but SAI reviews the scope, coverage and periodicity of such audits

SAI does Penetration testing, code injection tests etc.

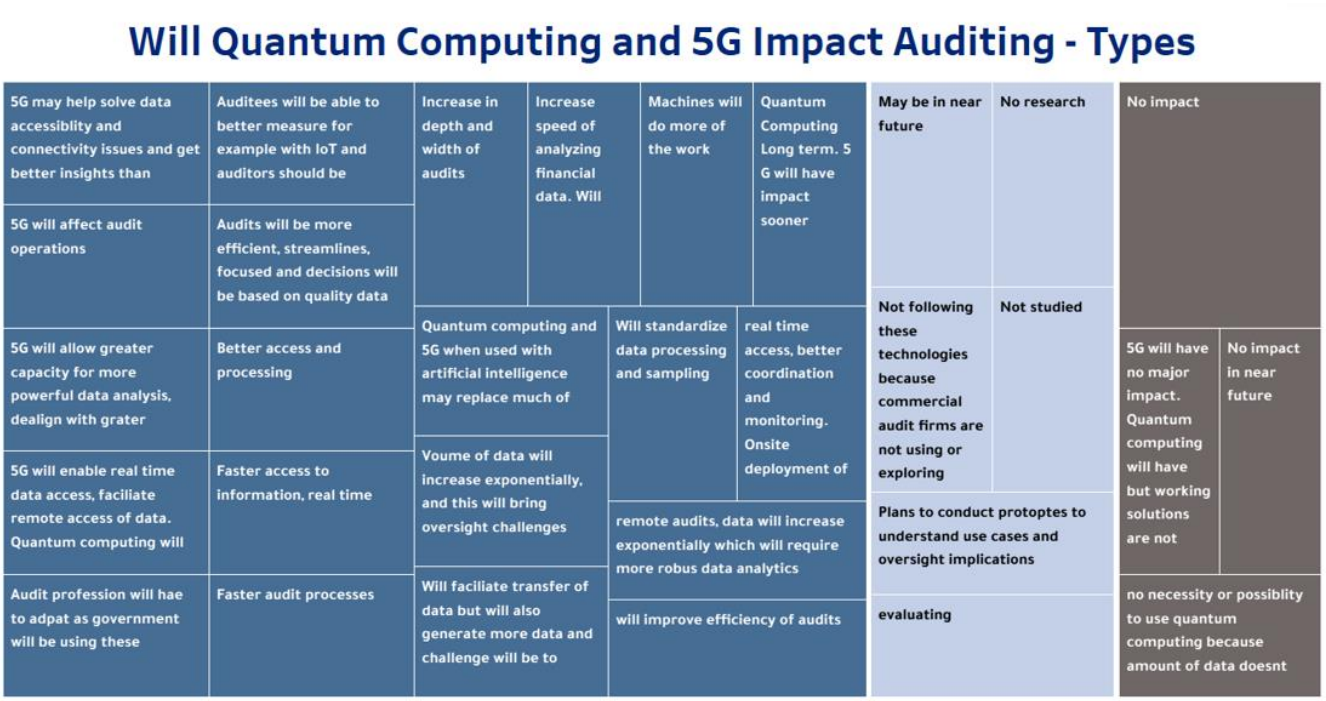
SAIs also shared with us the reasons. For example, there are specialized government agencies responsible for auditing advanced cybersecurity. Only one SAI explicitly said that they perform penetration testing and code injection tests etc. One SAI said that though an external agency performs such audits, they review the scope, coverage and frequency of such audits performed by the external agency.

Impact of Quantum Computing and 5G on Audit

One of the mandates for WGISTA is to study the impact of Quantum Computing and 5G on the public sector auditing profession. The survey results show that 53 percent of SAIs consider these are important technologies and see that these will impact their work; while 11 percent of the responses didn't see these as important technologies for auditing and 36 percent were not sure.

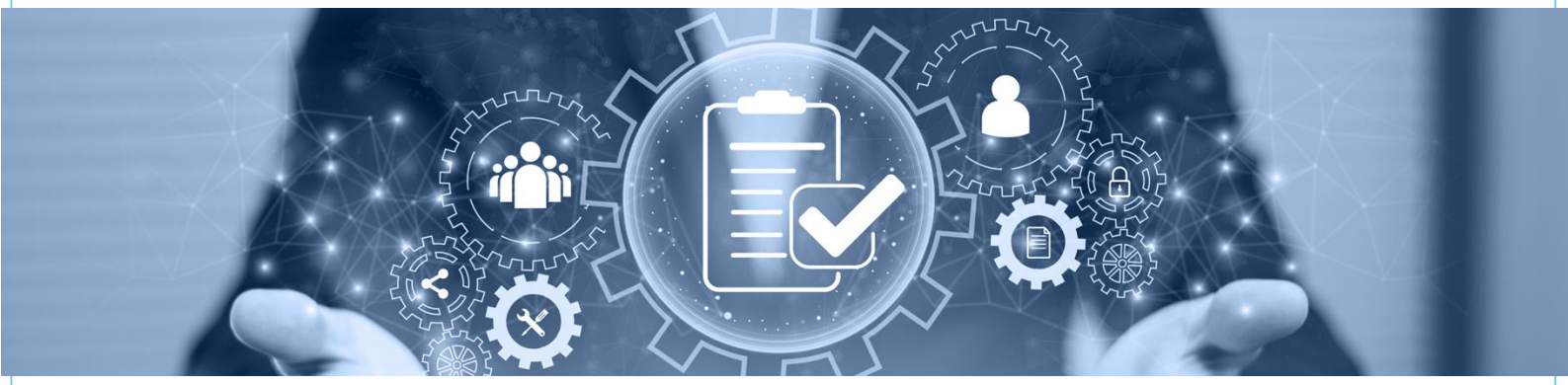


For example, SAIs consider that 5G may help with real time data analytics. Data will not only increase exponentially but its types will also change. One of the responses stated that the combination of Quantum Computing, 5G and AI might replace much of the auditor's work. Below is a detailed figure outlining all of the various response.



Experts Interviews/Views

Purpose: To summarize key information provided by subject matter experts on the potential impact of emerging technologies, including Blockchain and Artificial Intelligence on auditing.



Methodology	We developed a data collection tool and contacted nine subject matter experts to obtain their views on a variety of topics related to the impact of science and technology on auditing. We received written responses to structured questions from five experts: We also reviewed the information they provided, including weblinks to journal articles. The information from these sources is summarized below. (Note: interview questions are available in the appendix)

All comments noted below are attributed to the experts:

Blockchain Technology and Public Sector Applications

Maturity

Blockchain technologies have matured significantly and are ready for mainstream government applications. The latest generation of Blockchain-based systems, such as Avalanche and Solana, offer ease of implementation, cost, security, scalability and user experience benefits that are competitive with traditional databases. These systems are multiple orders of magnitude ahead of the first-generation systems such as Bitcoin and Ethereum version 1.

Blockchain engineers have addressed three long-standing challenges: scalability; compliance, and user experience. Regarding scalability, modern Blockchains such as Avalanche provide speeds that are far faster than VISA. In regard to compliance, new Blockchain options, such as Avalanche and Dapps (distributed applications built on Blockchains) do not need to share a single chain, which enables their performance to be isolated from other use cases.

Regarding user experience, new wallets, such as Core Wallet, are easier to use. They provide a seamless experience for users who are not familiar with cryptography. They can interact with Blockchain technologies, sometimes without knowing they are doing so.

Blockchain is currently disrupting the finance industry and has the potential to disrupt governmental processes due to the benefits of transparency and auditability. If the government develops a regulatory framework for Blockchain, this may further incentive the financial sector to invest in Blockchain, which will continue to advance Blockchain technologies and broaden its potential future use.

Government applications

Blockchain technologies can be used to enhance a variety of government services. For example, it could improve the management and distribution of government benefits, such as food stamps. Also, it could streamline accounting practices, augment transparency in government bids, and automate polling and opinion collection in local governments, among other uses.

In addition, Blockchain can be used in document verification, identification, and evidence preservation. For example, it could revolutionize the notary industry by preserving legal evidence collected from the internet in countries where the public has limited trust in the legal system.

Governments will need information technology professionals who can build, develop or procure Blockchain solutions. Governments need to anticipate areas of growth and get ahead of it. There is an increasing demand for Blockchain in the government, which is spurred by Blockchain technology savvy individuals coming from compliance, law enforcement and regulatory finance backgrounds. Latest generation systems, such as Avalanche, Cosmos, and Polkadot, provide a different architecture that allows entities to bring up a separate chain with its own, jurisdiction-specific rules. As a result, it is no longer a one-size-fits-all paradigm and there are more options available.

Regulation should never be used to shift the burden of law enforcement from professionals onto commercial entities. Just as a local store would not have the capacity to request identification for every single sale, the burden of Know Your Customer (KYC) and Anti-money Laundering (AML) related enforcement cannot be forced onto every single application. Doing so is burdensome and would shift development in this area off-shore and affect the United States' position as a leader in technological innovation.

Challenges

Blockchain technologies have several barriers to deployment. First, it is challenging to obtain high-quality, clear, scientific, trustworthy data to base decision making. As an emerging technology, benchmarks are not well-established, terms are not defined clearly, and there is a lot of misinformation. A more scientifically rigorous approach for Blockchain characterization, nomenclature and comparison is needed. Second, it is difficult to identify developers that are trained in these emerging technologies. Third, it is difficult to ensure the correctness of Dapps (distributed applications built on Blockchains). While there is a burgeoning field of auditors who specialize in smart contracts, Blockchain applications are not widely supported. New techniques for automatic program verification are promising, but they are not yet widely deployed or adopted.

Artificial Intelligence (AI) Technology and Public Sector Applications

Maturity

Artificial Intelligence (AI), machine learning, and the algorithmic tools that underpin these technologies have matured significantly over the past 10 years.[b] These technologies are now widely used throughout industry and government. Private and public sector organizations have invested in AI to create new or enhance existing capabilities. As AI has matured, there is an increasing awareness of its potential to enhance performance, productivity, effectiveness, and improve service delivery.

AI has matured to the extent that it can be used in audit systems across a variety of domains (e.g. financial, environmental, and health regulation). Government enforcement agencies face the challenge of allocating scarce resources for auditing regulatory non-compliance and AI-assisted auditing can address those limitations. The effectiveness, reliability, and auditability of AI systems will greatly affect its ability to reach mainstream adoption. The legal and regulatory environment, as well as leadership, hiring, and training (e.g. preparing personnel to use AI) will also affect AI adoption.

Government applications

According to a recent survey of the use of AI in the federal government, about half of U.S. agencies have experimented with or are currently using AI tools.[67] AI is currently being used to improve government operations across a range of areas, including: (1) enforcement (tasks that identify or prioritize targets for agency enforcement action, such as facial recognition systems by the Transportation Security Administration; (2) adjudication (tasks that support adjudication decisions about government benefits or rights, such as the system by the Social Security Administration to adjudicate long-term disability benefits; (3) regulatory research, analysis and monitoring (tasks that collect and analyze information to shape agency policy making, such as Food and Drug Administration analysis of adverse drug effects; (4) public services and engagement (tasks that support the direct provision of services to the public or facilitate communication with the public for regulatory or other purposes, such as agency analysis of submitted rulemaking comments; and internal management (tasks that support agreement management of resources, including employee management, procurement, and maintenance of technology systems, such as the Department of Health and Human Services tolls to assist procurement decision-making.

[b] Artificial Intelligence (AI) and machine learning are closely related but distinct areas of computer science. AI is used to create intelligent machines that can simulate human thinking and behavior while machine learning is a subset of AI that allows machines to learn from data without being programmed explicitly. Because the terms are often used interchangeably, for the purposes of this summary, we refer to AI, which encompasses machine learning and the algorithmic tools they are based on.

AI-based tools already touch many aspects of government and the pace of deployment is expected to accelerate. It is believed that AI could unleash the power of administrative data by helping to extract usable information form the government's massive data streams, reduce the costs of core functions by automating manual processes, and improve the quality of decisions. Above all, AI can potentially make government performance more efficient and effective.

A recent use case highlights broad lessons for AI deployment and its use in adjudication for making complex decisions in the public sector. Specifically, the one U.S. department—Social Security Administration (SSA)—developed and deployed an automated AI system to enable adjudicators to check draft decisions more quickly.[68]

These actions improved SSA's overall speed of caseload processing and shortened backlog in their examiners' caseload. SSA achieved successful outcomes by piloting the AI systems and taking steps to overcome roadblocks. For example, after early requests for additional staffing to develop AI-capabilities were rebuffed, SSA first set about freeing up resources to improve productivity performance standards from their staff.

As productivity rose, SSA gained more latitude to branch out and move existing resources into more ambitious projects. Eventually, SSA sought permission for a small budgetary expansion to expand it quality assurance efforts and supplemented this allocation by reprogramming much of its attrition hiring into quality assurance.

These staff performed the critical work of developing the AI tools for adjudication, like data labeling, which provided the foundation for them to eventually deploy their AI-based system. SSA built its internal staff capacity, which included provided technical training to help staff understand the new technology noting that staff may be skeptical about using the algorithmic tools.

Another use case highlights AI's ability to promote more efficient and effective delivery of government services, including health care. For example, according to a recent study on machine learning system that was used to predict language needs for contact tracing intake interventions COVDI-19, AI can improve patients' health outcomes, reduce case completion time and improve patient and contact tracer engagement.[69]

Machine learning systems for language matching were deployed that algorithmically identified Spanish speakers and routed them to Spanish speaking contact tracing staff.

In addition, researchers have explored the use of AI-based systems to audit the Internal Revenue Service (IRS). Based on a two-year collaboration with the IRS, researchers analyzed masked audit data to help detect under-reported tax liability.[70] There is growing interest in the application of AI to detect fraudulent financial statements.

Given the rapid rise of AI in new domains, including auditing, the operational accuracy of AI-based systems needs to be evaluated. Government should develop metrics for measuring the success of AI tools. Rather than focus entirely on efficiency or return on investment, government should develop evaluation metrics that are tied to the agency's broader mission, as well as standards of algorithmic accountability. Algorithmic accountability refers to algorithmic decisions that do not create discriminatory or unjust impacts when comparing across different demographics.

Facial recognition technology is the most visible/controversial example of the use of AI due to concerns about machine learning bias.[c] Independent audits serve an important role in mitigating risks from this bias and validating AI-based facial recognition technology.[71]

AI-based audits or "algorithmic audits" can enhance and supplement traditional internal audit process. However, continued work is needed to make algorithmic audits work, including the intentional design of an audit ecosystem that enables the effective participation of third parties. As it continues to deploy AI-based solutions, the government needs to design audit processes that are fully independent and removed from any real or perceived conflict of interest. Designated third parties provide the necessary independence.

The government needs to explain and justify their use of algorithms as well as related design decisions and the overall impact of the AI-based systems on the public. Even though AI technologies are sophisticated and complex systems, the government needs to overcome institutional tendencies to use "black box" methods, which involve testing or deployment of AI without clear understanding of how an algorithm arrives at its predictions.

To promote accountability, the government needs to open the black box of algorithm design. This can be done within or outside of the auditing framework. By developing an auditing framework and being deliberate in AI-design with lessons learned from other industries, the government can encourage trust in the AI-based systems and avoid the perception that the results are "rigged" or predetermined.

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[c] Machine learning bias is a phenomenon that occurs when an algorithm yields biased outputs that stem from prejudiced assumptions made during the algorithm development.

Challenges

There are several challenges that must be overcome to encourage growth of AI-based audit system. The standards and scope of an "algorithmic audit" may be unclear, which can lead to assessments that are unfocused and/or expensive. Audit targets could outright ignore or overlook audit result or use their knowledge to manipulate audit findings. Even well-executed algorithmic audit results could get co-opted by audit targets and used to disguise deeper failures.

The identification of audit targets and scope may be uncertain. Identifying audit targets is critical to ensuring that audits are applied to relevant parties and conducted for the right issues. Conflicts of interest could impair auditor objectivity and compromise the quality of audit results of algorithmic systems.

Auditors need to be free from potential conflicts of interest that could arise from non-disclosure agreements or financial conflicts. Auditor independence is critical to be able to confirm and verify performance claims made by the audit targets. As such, it is often beneficial to have the regulator select an auditor and use a central fund instead of direct payment from audit targets to pay auditors.

The application of Corporate Social Responsibility (CSR) framework offers lessons for developing a framework for auditing AI. CSR auditing is expensive and potential costs of diffuse audits are high. Due to the ambiguity of what is being audited, this may result in rubber stamping practices without in fact promoting CSR. Overall, the move toward AI audits without considering factors like third-party auditor scope, independence, access, standards, and transparency, risks ignoring lessons learned from the past.

While AI has been used in an array of different applications across the government, the use of algorithms in auditing is generally not disclosed in a transparent manner, making it hard to identify audit targets in the first place. There may be benefits to establishing a national incident reporting system to enable third parties to file complaints about algorithmic systems.

Regulators can use this information to identify specific priority targets and assess fees or penalties based on audit results. They could then incentivize third party auditors to inspect repeatedly flagged cases in this database through various means. When communities identify issues with algorithmic deployments, it can be difficult for them to articulate or find concrete evidence for such harm.[72]

To successfully deploy AI in the public sector, government must overcome organizational and personnel barriers, including trust with the public and make human capital investments and update outmoded data and computing systems. Also, additional efforts are needed to develop more systematic, ongoing, and legal ways of auditing algorithm that provides a framework for the effective external oversight of algorithmic systems.

Rather than taking steps to encourage all of government approach to AI deployment, it will be important to first set strategic priorities, identify the most promising areas for interventions, invest in such areas and deliberately pilot and test out AI-based systems. Human capital, computing resources, the data and policy environment (i.e. that are open to auditing) will be critical components as well.

While AI's potential is great, so are the stakes. Improperly designed algorithms can exacerbate bias and fail to produce outcomes that align with good judgment. Moreover, they could undermine government decision making and authority and heighten concerns that AI may be used to enable surveillance that could threaten privacy and civil

liberties and enhance government power. Algorithmic accountability and auditing can help provide the appropriate safeguards to govern the application of AI.

Best Approaches to review AI Powered Systems

There are multiple agreed upon approaches. One of the popular ones in mission critical systems is setting performance guarantees which means that the system must meet a minimum set of performance requirements in terms of accuracy, false positives, adaptability and others. New approaches now also utilize synthetic data to test the systems against changing environments and multiple scenarios (for example autonomous cars are trained in simulation environments that can replicate realistic rain, snow and other weather conditions). The same concepts can be applied to many AI systems.

AI powered systems are built on models that use a lot of data for training purposes and where the computational complexity can be quite high. Thus, reviewing these systems can be quite challenging. To understand whether these systems work as envisaged, the traditional product development life cycle should be thoroughly analyzed.

This will include making sure to get the requirements right (what the product is supposed to achieve), the design and implementation stages are fundamental, and a prototyping approach is normally more suitable here. Later stages, especially in terms of integration of the product, it is important to have a feedback-oriented verification and validation approach for every life cycle stage, whether it is for integration of specific modules or for system integration.

What makes AI systems different is also the time spent in data collection and preparation for system modeling and training. It is important to employ strategies and techniques that evaluate the relevance and quality of data to be used.

- Proper testing using dataset that is representative of all (or most) of the data that the model will be exposed to in production.
- Thoroughly check the performance metrics used in training the AI model and the precautions taken to ensure service quality.
- Review and analyze the training Datasets used in developing the model, to gain a better understanding of its potential capabilities and limitations.
- Ensure that there are monitoring mechanisms in place to flag any potential performance degradation due to data drift, concept drift, or other causes.

How Organizations can prepare and train for Artificial Intelligence

Micro-degrees are gaining popularity in the field. Successful organizations can utilize these training programs to upskill their talent. It is important to create a quality training programs which could be composed of multiple micro-degree-based ones or choose long structured trainings. In both cases it's important to customize the training objectives to the specific challenges and tools used in the organization

Preparation and training should be done at different levels and for different aspect of these systems. Senior Management/Executives would need to know how AI systems can help improve performance and cut cost. So, AI training for leadership & change management is key. Training should be provided for operational staff to understand the technical/functional aspect of AI-based systems.

Organizations must ensure that their employees are aware of:

- The applications (current and potential) of AI in their industry → All employees
- A general understanding of how AI models operate → some employees in every department
- A deep understanding of AI models → Employees in the technical teams

This can be achieved through participating in the various educational and training programs offered by government entities and educational institutes, and also the content available on the internet from reputable sources in the field.

What types of strategic investments an organization should consider?

The most effective approach is to recruit AI experts because it's not an easy skill to pick up. While organizations can upskill their talent to understand it and fill gaps, it remains challenging to implement in real applications. Thus, it is much more efficient to find talented individuals with proven track record in data engineering and AI deployment. These experts must work with the subject matter experts from the organization.

Investments would range from re-skilling/up-skilling employees to purchase of new and emerging technologies. However significant investment would go into the development/customization of products, their integration and testing within the work environment.

Strategically, organizations should aim to become AI-First organizations and make the necessary investment to achieve this goal.

Summary of Discussion & Future Outlook

The report attempts to cover all three dimensions of analysis in this environment scan. After reviewing the literature and the SAI survey responses from the Environment Scanning Survey, we also have looked at experts' views on emerging technologies, more specifically Artificial Intelligence and Blockchain.

There is no denying the fact that public sector auditing is in the middle of 4th industrial revolution. And the emerging technologies that are empowering this shift are having implications for almost every profession and every segment of society.

As public sector auditors, we cannot ignore these technologies. While some of these technologies such as Quantum computing are not right here for end users, Google and other tech giants are working to bring end user targeted quantum computers within this decade.

The impact of these technologies on auditing is well established.

The critical questions are:

- What strategic steps should SAIs take to leverage these emerging technologies in their auditing profession?
- What steps can SAIs take to upskill and create "digitally fit" organizations for the next era of emerging technologies?
- Which technologies should SAIs prioritize out of these emerging technologies?
- What can WGISTA and INTOSAI do to support SAIs in this transitional phase?

As we heard from experts, the skills like AI and Data Engineering are not easy to acquire. One approach may be to bring in experts who would work with subject matter experts. The second approach is upskilling the existing work force, which would be a longer route. However, it appears that even the existing workforce would need to stay updated on direction of the emerging technology, regardless of whether SAIs engage external expertise.

SAIs need to understand that at the foundation of all these emerging technologies is *data* that is proliferating in size and changing in nature too. Therefore, data governance/management and data engineering skills should be given importance. Once data is available in a digital format, SAIs can use Advanced Data Analytics to more effectively extract and manipulate large amounts of data. The next logical step would be to build capacity in writing scripts to customize analysis.

Once a Supreme Audit Institution is on this step of maturity on the technology ladder, it may be the right time to start exploring machine learning and Artificial Intelligence.

As for the Blockchain, SAIs need to understand how this technology works and the risks that are associated with Blockchain. This is important because we already see some use cases of Blockchain in accounting and in governments service delivery.

Robotic Process Automation is a technology that can save a lot of time and help auditors focus on the important and creative stuff, leaving the mundane and repetitive tasks to digital robots. As we noted during Environment Scanning Survey, some SAIs are already experimenting with RPA.

We noted during the literature review that now, there are almost no Quantum Computing implementations in governments service delivery but given the pace of this technology, it will be only a matter of time before an end-user quantum computer arrives. SAIs may be well placed to make use of this technology because of the huge volumes of data they encounter in the performance of their work.

By leveraging high speeds of quantum computers, SAIs may be able to perform more complex data analytics. The technology may likely be beneficial for machine learning and artificial intelligence too. We understand that at this stage, SAIs need to remain engaged with developments on quantum computing so that they are not caught off-guard when the quantum computing technology arrives for end users.

WGISTA and INTOSAI can play a role in helping SAIs navigate the developments in emerging technologies by leading research efforts and studying the impact of these technologies on a regular basis. Studying the changing landscape of emerging technologies and their maturity for practical use should be a regular feature of WGISTA efforts. Some of the possible areas of future intervention by WGISTA are listed below:

- Publishing detailed and educative series of guides/white papers from SAI's perspective on emerging technologies (i.e., case studies). Comprehensive and individual guides/white papers on related topics.
- We understand that many of these emerging technologies are not at that stage where regulatory environment has evolved but WGISTA can undertake projects to write guidance frameworks on these emerging technologies from an auditor's perspective, especially focusing on auditability, risks, and controls.
- WGISTA may also consider creating an experts group of SAIs with domain expertise to come together and hold group discussions on a subtopic of interest and document/record the discussion for the benefit of all SAIs.
- WGISTA may consider creating an INTOSAI innovation lab which can provide SAIs with a space to explore innovation. There may also be a possibility for it to become an INTOSAI Center of Excellence of Emerging Technologies for Auditing that provides trainings on emerging technologies.
- WGISTA may consider MoUs with entities working on emerging technologies in the government sector and international accounting and auditing bodies to share knowledge in a collaborative framework.
- WGISTA may publish biannually a State of Emerging Technologies Report for SAIs.
- WGISTA may consider a series of webinars where they invite industry leaders and experts on topics of interest related to emerging technologies from public sector auditors' perspective.

By use of these technologies, auditors can achieve the following and possibly a lot more:

- Full coverage of data, with a clear shift away from sample based audit of a fraction of the population.

- More efficient audit processes which would allow auditors to spend more time on intelligent review of controls and in-depth analyses which will improve audit quality and at the same time bring more beneficial reports for the clients.
- Continuous auditing which has the potential to speedup timelines of audit outputs when compared with auditing on historical data.
- More reliable audit evidence when technologies like AI, RPA and Blockchain are used collectively.
- Better understanding of client systems, especially where auditors would encounter these latest technologies.
- Improved risk assessment of client by using AI to analyze data from non-traditional sources like email, social media, internet, public statements etc.
- Intelligent document analysis by using technologies like Optical Character Recognition or Natural Language Processing
- Trained AI tools can be used to identify outliers and errors in data.
- Using technology to review unstructured data and identify anomalies by cross linking with other traditional data sources.

As we can note, the possibilities of technology are endless and ever evolving. Supreme Audit Institutions would need to adopt a culture of innovation and invest in recruiting and upskilling technology skills to stay relevant in the times to come.

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Appendix:

Interviews with subject matter experts (Blockchain):

1) What are some of the most promising uses of Blockchain Technology that the governments are likely to adopt or have already adopted?

a. What industries or sectors do you think will have the fastest rate of adoption of Blockchain technologies?

2) Please discuss the maturity of Blockchain technology and if you anticipate that digital currencies or assets based on Blockchain technology may be deployed by governments in the near future?

a. When would you consider a blockchain implementation to be mature and competitive with databases in terms of ease of implementation, cost, security, scalability, and other factors entities typically consider when making IT decisions?

3) To what extent do you think that Blockchain can be used as a technology to preserve audit evidence? If yes, what are the challenges that an organization like an auditing entity that audits databases would have to overcome to use a Blockchain based evidence collection and preserving systems?

4) What kind of human resources capacity and technical challenges are governments likely to face in auditing and regulating the integrity of Blockchain based assets and systems?

5) To what extent do you think that governments should focus on building human resources that have deep understanding of Blockchain based systems?

a. When do you anticipate Blockchain technology will be mature enough for mainstream government applications?

b. How do current statutory or regulatory requirements influence the adoption and use of Blockchain technologies?

Interviews with subject matter experts (AI):

1) What are the best approaches to critically review Artificial Intelligence powered systems to understand if they are working as envisaged and if there are any weaknesses in design?

2) To what extent do you think governments will utilize Artificial Intelligence to achieve their respective missions in the future? If yes, when do you anticipate that Artificial Intelligence will be mature enough for mainstream government applications?

a. What factors will influence Artificial Intelligence's ability to reach mainstream adoption?

3) Please describe how organizations can most effectively prepare and train their personnel resource for to use Artificial Intelligence in the future.

4) What types of strategic investments (personnel training / skill development, financial and technical resources, etc.) should an organization consider if it wants to scale up its capacity to implement Artificial Intelligence?

5) Based on your observations to date, which sectors of the government (or industries?) seem likely to adopt Artificial Intelligence technologies the most quickly?

6) To what extent do you anticipate governments using Artificial Intelligence in their financial operations or accounting/auditing?

Interviews with subject matter experts (Emerging Tech):

1) Please describe your organization's views on emerging technologies and their application to auditing and program evaluation.

2) To what extent do you believe that newly emerging technologies may impact and/or potentially challenge the auditing sector?

3) Please describe which of the following technologies will be most relevant to future of audit and why: Robotic Process Automation, Advanced Data Analytics, Artificial intelligence, Quantum Computing, 5G? You can comment on more than one technology (or others that are not listed) as well. Please note, which if any of these technologies you anticipate being the most consequential / high impact to the field of auditing.

4) To what extent can Artificial Intelligence be used to help auditors in the future?

5) What kind of skills and technical expertise to auditors need to have in the future to audit systems that use Artificially Intelligence technology?

6) How can robotic process automation help auditors?

7) What challenges, if any, do auditing organizations need to be aware of when implementing robotic process automation?8) To what extent do you think Quantum Computing will be a technology of promise or concern for auditors?

9) To what extent, do you think, if at all 5G can impact the field of auditing?

10) What steps, if any, should as auditing organizations/auditors take to prepare for the rollout of 5G technology?

11) To what extent, do you think Blockchain technology can be used to preserve audit evidence? If yes, what challenges, if any, do auditing organizations that audit databases have to overcome to use a Blockchain based evidence collection and preserving systems?

12) To what extent, if at all, do you think that auditors should be familiar with the use of Blockchain technologies because their clients are expected to deploy these technologies?

a. How soon do you foresee that Blockchain technology will become mainstream in financial/accounting systems?

b. What can we do as auditors to keep pace with Blockchain adoption by our clients?