# III. The technologies

# 1. Blockchain and distributed ledger technology (DLT)

## A. What is blockchain technology?

(DLT) The term blockchain is often used in a generic way to refer to distributed ledger technology. However, technically speaking, blockchain is only one type of DLT, one that combines transactions in blocks and links them in a linear manner. Other DLTs validate transactions, not blocks, and link them in a non-linear way. However, what all these technologies have in common is their decentralized and distributed architecture and the use of advanced cryptographic techniques. This Report, like many others, uses the terms blockchain and DLT interchangeably.

Blockchain is a type of sophisticated cryptographic decentralized and distributed ledger architecture, a continuously growing list of records. It has the capability to move any kind of data securely among participants in the network (called nodes) on a peer-to-peer basis and, at the same time, make a record of that change, movement, or transaction available instantly, in a trusted and immutable manner to all participants. No entity controls it (it is decentralized) and data is distributed among the participants in the network (each participant has a copy of the records). The decentralized and distributed nature of blockchain, combined with the use of advanced cryptographic techniques, makes it a highly secure technology.

*Blockchain is now being explored or used in areas as diverse as health, education, identity management, voting, food traceability, transportation, document provenance, trade finance, and of course Customs processes.*

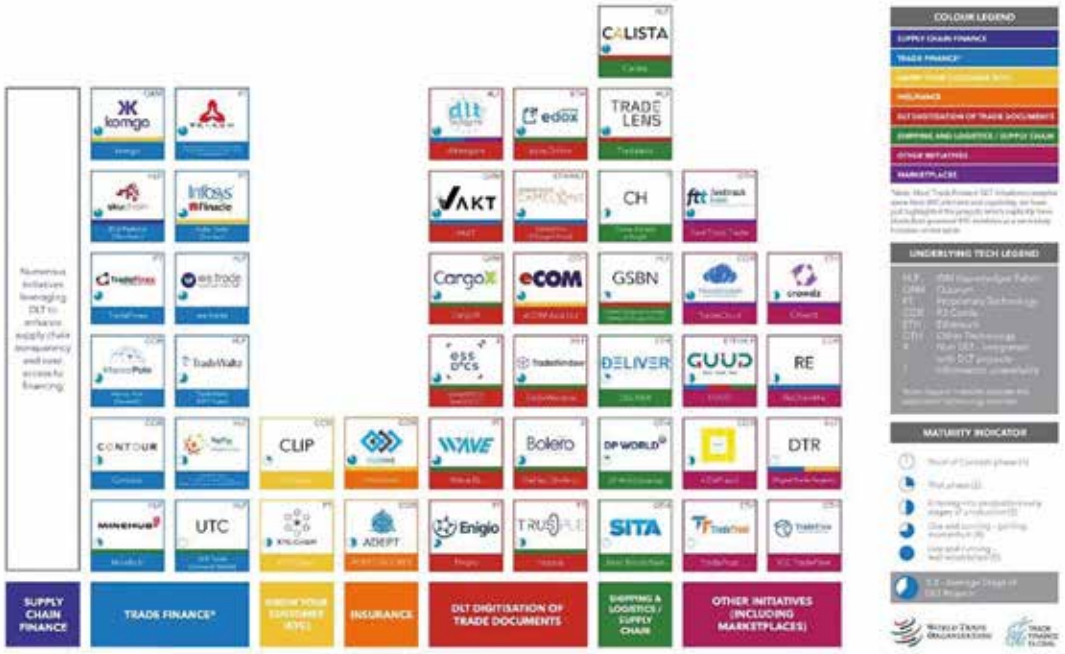
Transactions or blocks added to the ledger are linked to one another and time-stamped, making the technology inherently resistant to modification of the data. Data recorded on a blockchain cannot be altered retroactively without altering all previous records, which requires collusion of the network majority. The immutability that blockchain provides, combined with the fact that records are linked to one another, makes blockchain an extremely useful technology to track the full chronology of events, e.g. along the supply chain.

Blockchain was invented by Satoshi Nakamoto in 2008 for use in the cryptocurrency bitcoin, as its public transaction ledger. The invention of the blockchain for bitcoin made it the first digital currency to solve the double-spending problem without a need for a trusted authority or central server. The bitcoin design has been the inspiration for other applications.

In recent years, the number of projects leveraging the technology for applications other than cryptocurrencies has been skyrocketing. Blockchain is now being explored or used in areas as diverse as health, education, identity management, voting, food traceability, transportation, document provenance, trade finance, and of course Customs processes (see Box 1 below).

*Box 1: DLT case studies in international trade*

Beyond the use of blockchain by Customs (see section 'c. Implementation by Customs in 2021' below), many projects leverage blockchain technology to digitize trade documents and, through this, solve the double-spending issue, to facilitate the sharing of information among supply chain stakeholders and streamline processes, and to enhance supply chain management (see figure below).




*Source: DLT projects in Trade: Where do We Stand? (2020)*

Many projects have also emerged that use blockchain to trace products along the supply chain with a view to asserting ethical, social or environmental claims; providing customers with greater transparency; tracking tainted products, or combatting fraud. Examples in this field include projects by:

- **Everledger**, which has placed millions of diamonds on a blockchain to verify the provenance (origin and authenticity) of precious stones to curb the problem of counterfeits and 'conflict diamonds'. Entries include dozens of attributes for each diamond, including the colour, carat, and certificate number, which can be inscribed by laser on the crown or girdle of the stone;

- **Provenance**, a company which enables enterprise food, drink, beauty and fashion brands to prove their social and environmental impact;

*Continuation box 1: DLT case studies in international trade*

- **LVMH**, Cartier and Prada, which in April 2021 launched the Aura Blockchain Consortium, the world's first global luxury blockchain. Each product is given a unique digital identifier during the manufacturing process that is recorded on the Aura ledger, allowing customers to access the history of the product, including its origin, components, environmental and ethical information, proof of ownership, a warranty, and care instructions;

- **IBM Foodtrust**, which is a permissioned network that connects participants across the food supply to increase food safety, reduce supply chain efficiencies, minimize waste, and enhance consumers' trust;

- **Aircraft manufacturers** which are exploring how a blockchain might track disparate parts of their jets as they make their way from machining shops to the tarmac. SITA, an IT solution provider for 90 per cent of airlines, partnered with ShoCard to develop a passenger identity management app for airlines. The app combines facial recognition technology and blockchain-based data to streamline passenger processing at airports.

Various important features make blockchain a useful technology to leverage in international supply chain management:

### 1. Increased security

- The decentralized and distributed architecture makes blockchain-based systems more resilient as it eliminates the single point of failure.
- The use of advanced cryptographic techniques makes blockchain highly secure and quasi-immutable. Once added to the blockchain, records are tamper-proof, i.e. they cannot be modified.

### 2. Greater transparency

The full chronology of events (e.g. transactions) that take place are tracked, thus allowing anyone with access, including regulatory authorities, to trace or review prior transactions, providing a full audit trail.

### 3. Greater efficiency

- Blockchain's decentralized and distributed nature and the use of advanced cryptographic techniques allow participants to interact on a peer-to-peer basis. It provides "trust" between and among unknown parties to transact business and exchange information without an intermediary.
- The use of smart contracts, i.e. computer programs that self-execute when certain conditions are met, makes it possible to automate transactions, thereby further reducing processing costs.

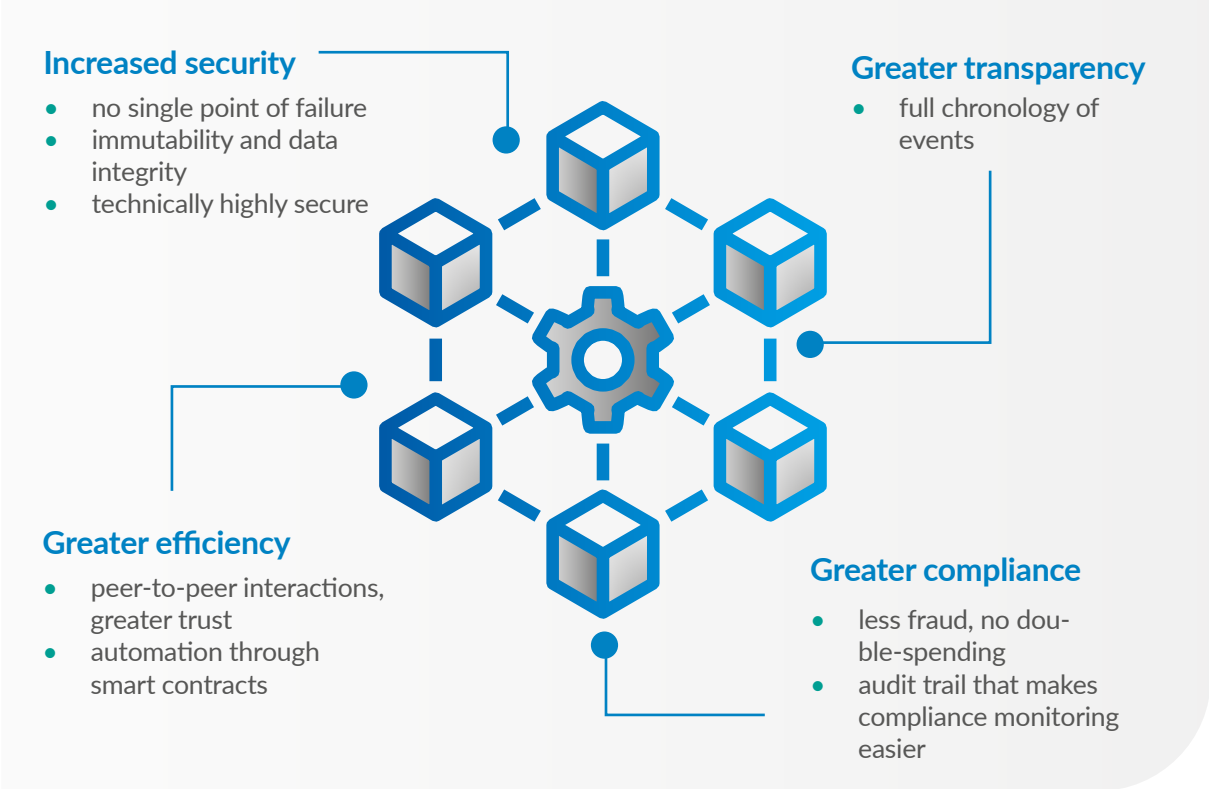
### 4. Greater compliance

- Transactions are verified and approved by consensus among participants in the network, making fraud more difficult.
- Blockchain solves the double-spending problem, making documentary fraud more difficult. Under traditional approaches to trade digitalization, copying and replicating electronic documents is easy. Keeping track of who possesses the original can become particularly complex and lead to double-spending problems. The immutability and traceability

features of blockchain offer the guarantee that the electronic documents are authentic and have not already been "spent."

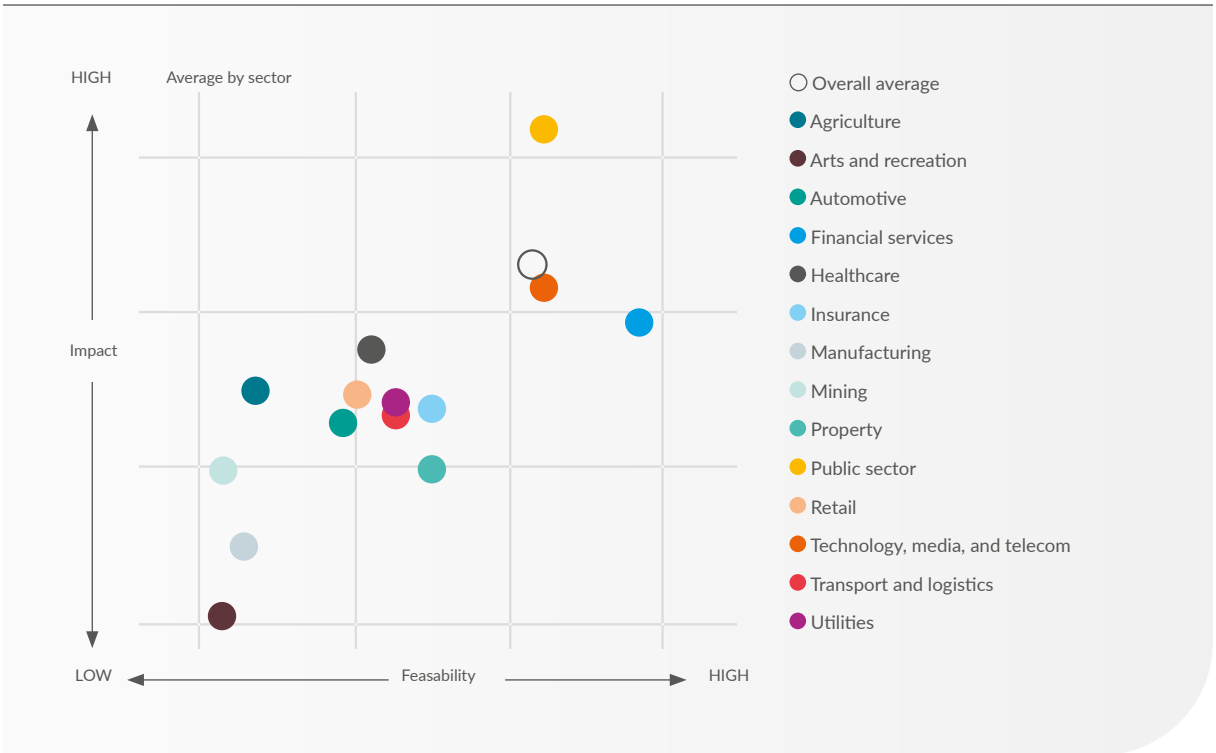
- By providing a full audit trail of transactions, blockchain makes compliance monitoring easier.

*Figure 1: What are the blockchain benefits for trade?*




*Blockchain is a useful technology to leverage in international supply chain management.*

*Figure 2: Blockchain opportunities by industrial sector*




*Source: Digital McKinsey*[6]

Blockchains can be public (there is no central entity controlling the network and everyone can read and write on the ledger) or private (a single entity or a group of entities – consortium - manages the network). In addition, participation in the network can be subject to certain conditions – permissioned blockchains – or open to anyone – permissionless blockchains. An increasing number of projects are using hybrid approaches that combine components of both public and private blockchains, to benefit from the higher level of security that public blockchains offer and higher scalability of private blockchains.

*Although blockchain technology presents interesting features in terms of security, immutability, transparency, traceability and automation, its wide-scale deployment currently hinges on various challenges.*

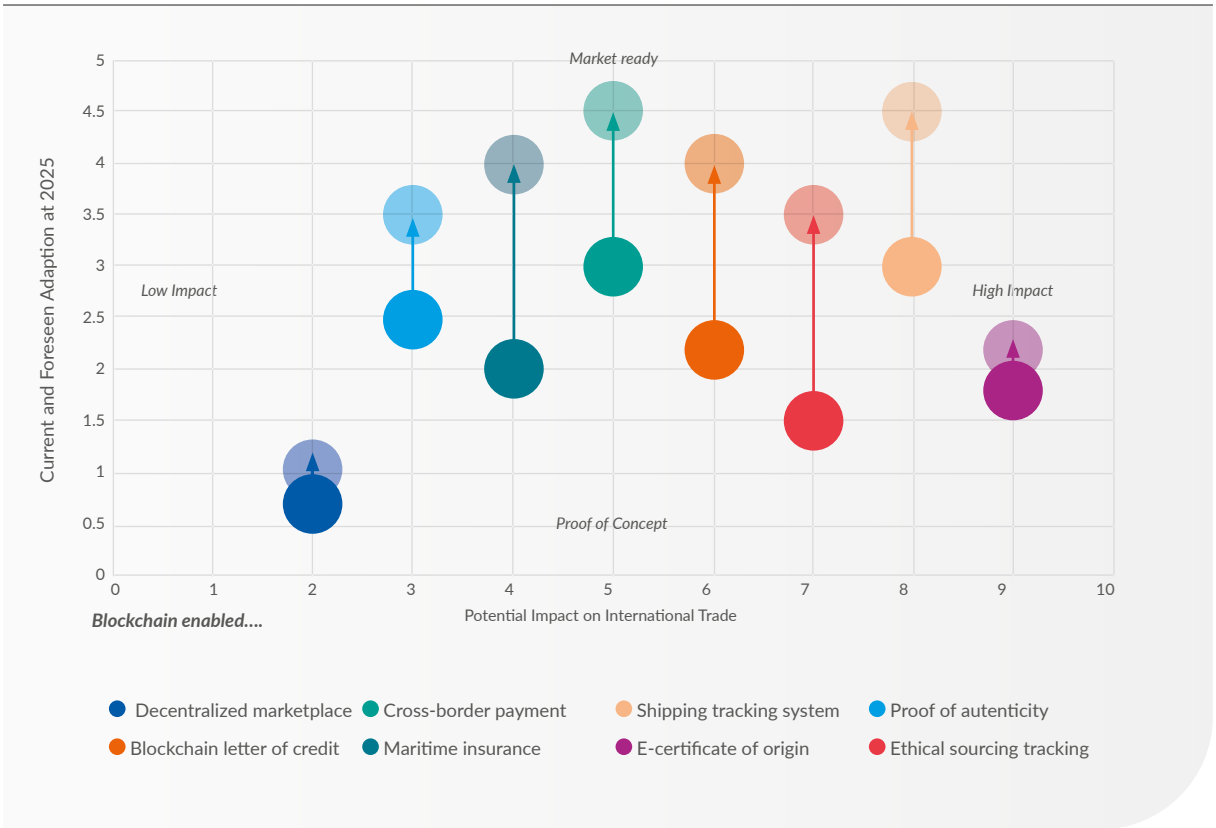
Most projects launched in relation to trade and Customs are permissioned or hybrid blockchains.[7]

With the blockchain technology, efficiencies in the supply chain can be improved not only in the reduction of intermediaries and paper/manual tasks but also in improving certainty and predictability based on the reliable real-time data available to all the stakeholders in a supply chain participating in a blockchain. This allows for traceability and end-to-end visibility, thus enhancing supply chain security and facilitation. To begin with, however, it would be necessary to map the data elements at different points in time to demonstrate what the inputs are and at what level, as well as what the outputs are, perhaps at different levels.

6 B. Carson, G. Romanelli, P. Walsh, and A. Zhumaev (2018), "Blockchain beyond the hype: What is the strategic business value?", McKinsey & Company, Digital McKinsey, https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/blockchain-beyond- the-hype-what-is-the-strategic-business-value, accessed on 13 January 2019

7 WCO-WTO paper "The Role of Advanced Technologies in Cross-border Trade: A Customs Perspective", 2021

*Figure 3: Current and future adoption of the case studies*




*Source: IDATE Digiworld 2019*[8]

Although blockchain technology presents interesting features in terms of security, immutability, transparency, traceability and automation, its wide-scale deployment currently hinges on various challenges (see also Box 3). Scalability remains limited, existing blockchain networks and platforms do not "talk" to one another, and there are a number of unresolved legal issues, ranging from the legal status of blockchain transactions to the question of liability.[9]

It might also be asked whether blockchains are truly impenetrable to cyber security issues. Last but not least, implementing blockchain systems can be relatively more costly.

8 *Scientific Foresight Unit (STOA), EPRS | European Parliamentary Research Service, "Blockchain for Supply Chains and International Trade" (2020), https://www.europarl.europa.eu/RegData/etudes/STUD/2020/641544/EPRS_STU(2020)641544_EN.pdf*

9 *WTO World Trade Report 2018: https://www.wto.org/english/res_e/publications_e/world_trade_report18_e.pdf*

*Figure 4: Five blockchain myths*

**Five common blockchain myths** create misconceptions about the advantages and limitation of the technology.

| | Myth | Reality | |
|---|---|---|---|
| 1 | **Blockchain is Bitcoin** | ● Bitcoin is just one-crypto-currency application of blockchain | ● Blockchain technology can be used and configured for many other applications |
| 2 | **Blockchain is better than traditional databases** | ● Blockchain's advantages come with significant technical trade-offs that mean traditional databases often still perform better | ● Blockchain is particularly valuable in low-trust environments where participants can't trade directly or lack an intermediary |
| 3 | **Blockchain is immutable or tamper-proof** | ● Blockchain data structure is append only, so data can't be removed | ● Blockchain could be tampered with if >50% of the network-computing power is controlled and all previous transactions are rewritten – which is largely impractical |
| 4 | **Blockchain is 100% secure** | ● Blockchain uses immutable data structures, such as protected cryptography | ● Overall blockchain system security depends on the adjacent applications – which have been attacked and breached |
| 5 | **Blockchain is a "truth machine"** | ● Blockchain can verify all transactions and data entirely contained on and native to blockchain (eg. Bitcoin) | ● Blockchain cannot assess whether an external input is accurate or "truthful" – this applies to all off-chain assets and data digitally represented on blockchain |

*Source: Digital McKinsey*

## B. Potential use in Customs and border management

Blockchain's potential to facilitate Customs processes is multifaceted, from Customs clearance to inter-agency cooperation, certification, identity management, compliance management, revenue collection and post-clearance audit. Through this technology, the same copy of a ledger is instantly available to all parties at different nodes in the most updated, trusted, secure and immutable manner, obviating the need to maintain separate ledgers by each party as per the current practice.

Considering the potential of blockchain technology, the WCO and the WTO have been exploring the use of this technology in the Customs domain for the last few years (see Box 2 below).

*Box 2: Discussions on blockchain at the WCO and the WTO*

### WCO

An exploratory discussion was held at the April 2017 Permanent Technical Committee (PTC) meeting, where IBM shared its perspective and the preliminary outcomes of the pilot, Global Trade Digitization (GTD), which later grew into TradeLens, a joint venture between IBM and Maersk.

Following that, this topic was discussed from a more technical perspective at the May 2017 Information Management Sub-Committee (IMSC) meeting, and in most of the WCO technology conferences and WCO working body meetings that followed. The May 2017 IMSC explored potential opportunities for the use of blockchain technology, and suggested collecting case studies and outcomes of pilots and other emerging initiatives concerning its use in regulatory and supply chain management processes. It also identified several case studies of blockchain technology in Customs business processes and overall supply chain management for carrying out future work through engagement with relevant stakeholders and technology experts/solution providers.

Furthermore, in June 2018, the WCO issued Research Paper No. 45 "Unveiling the Potential of Blockchain for Customs" to identify possible case studies and uses of blockchain for Customs and other border agencies, with a view to improving compliance, trade facilitation, and fraud detection, while touching on associated adjustments in legal and regulatory frameworks. The research paper elaborated the above concepts in more detail.

More recently, at its December 2021 meeting, the Policy Commission endorsed the launch of a Feasibility Study on a Global Customs Data Exchange Platform which is intended to be based on blockchain technology. This clearly indicates the interest of the WCO Membership in making use of this technology and its benefits.

### WTO

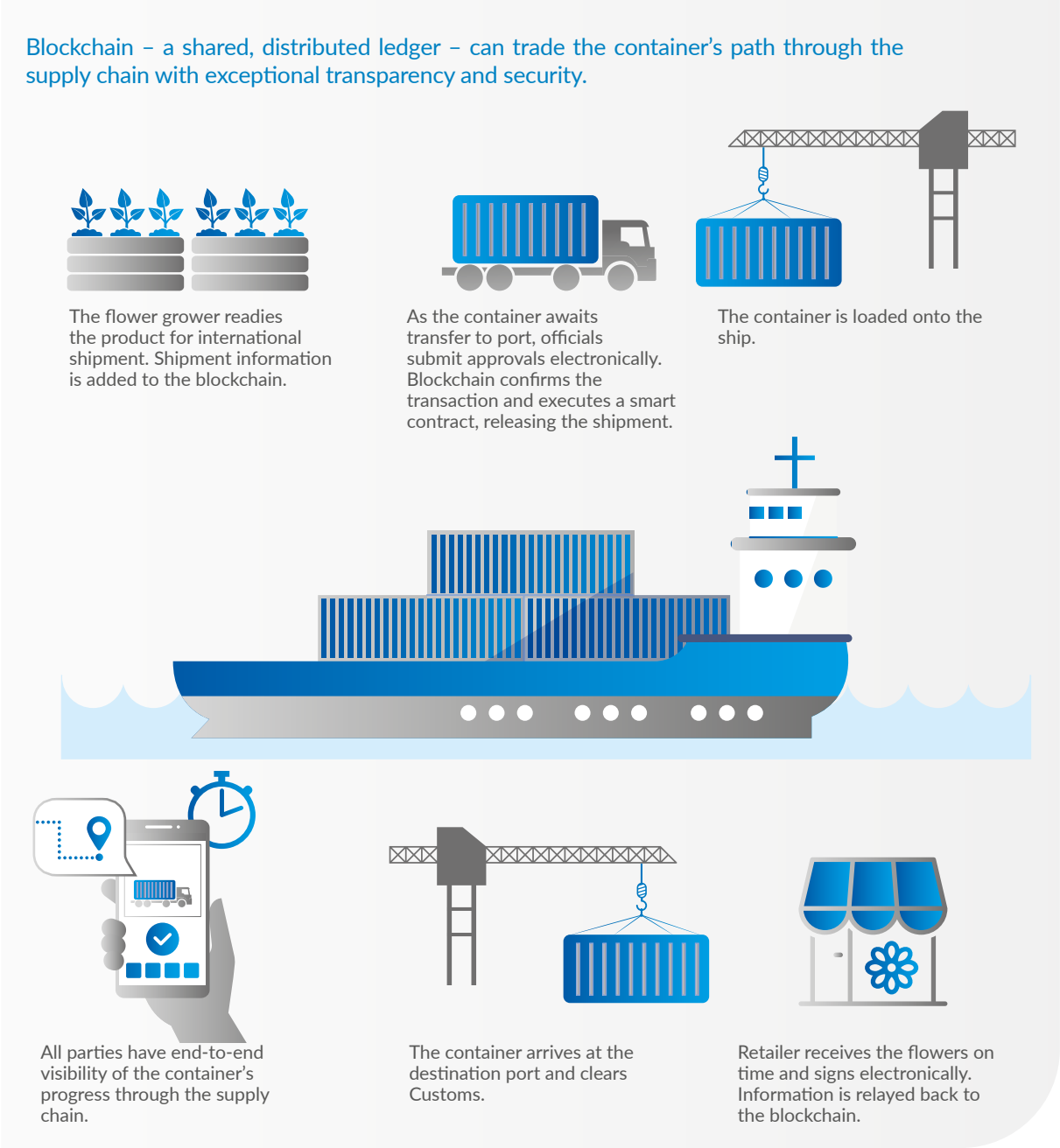
A research workshop held at the end of 2018 explored the potential of blockchain/DLT to facilitate trade finance processes, transportation and logistics, and border procedures. A number of case studies were presented to highlight the potential of the technology. The workshop also discussed challenges raised by the use of blockchain for trade. Discussions highlighted the need for greater coordination between all stakeholders to address interoperability and regulatory challenges.

Following that, two Global Trade & Blockchain Forums were organized in 2019 and 2021. The 2019 Global Trade & Blockchain Forum provided an update on case studies aimed at facilitating international trade using blockchain, in trade finance, transportation and logistics, and border procedures. It also explored the potential of the technology for trade in agriculture and intellectual property, and introduced the current patent landscape of blockchain-related innovations, its trends, and new challenges arising. A session on standards addressed whether disruptive technologies, including blockchain, might lower the cost of certification for MSMEs and developing countries or whether they might create new barriers, the challenges that might arise as many standards were being developed in different organizations, how regulators would deal with risks, and the need for cooperation. The session discussed examples such as self-driving vehicles, pharmaceuticals, and agriculture, and highlighted the importance of coherent standards development across the Internet of Things, autonomous systems, and blockchain. Discussions highlighted the need for multilateral work on interoperability/standardization, the regulatory framework, awareness raising and capacity building. The importance of fostering a multi-stakeholder dialogue was stressed.

*Continuation box 2: Discussions on blockchain at the WCO and the WTO*

The 2021 Global Trade & Blockchain Forum explored the opportunities that blockchain opens to enhance transparency and efficiency of supply chains, and discussed issues related to digital identity and trade and how trade agreements could be leveraged to develop a common framework for digital identities. Speakers also noted the need to accelerate work on standardization, and called on governments to quickly put in place regulation on e-signatures and electronic transferable records.

*Figure 5: Blockchain – a shared, distributed ledger*




*Source: IBM*[10]

10 *W. Lehmacher, "Why blockchain should be global trade's next port of call" (2017), World Economic Forum, https://www.weforum.org/agenda/2017/05/blockchain-ports-global-trades/, accessed on 13 January 2019*

As for the Customs administrations and other border agencies, solutions based on blockchain can significantly improve their capacity for risk analysis and targeting, thus contributing to greater trade facilitation.

Blockchain technology can potentially be used in Customs business processes to validate the transactions/actions of different parties in the international supply chain through permissioned blockchains - clearly defining roles, responsibilities, levels of access, and validation rights for each party. It could equip Customs with the necessary tools to tackle problems of compliance, as it provides an unbiased tool essentially designed for uploading and sharing information between unrelated parties. This can help in the end-to-end integrated supply chain management in a transparent and trusted manner.

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Going forward, the following specific case studies in Customs and border processes have been identified for future work:

### Customs declaration

Creation of Customs declaration documents is a very complex task, involving multifarious activities. There are challenges in collating (often manually) the correct information from various documents and various stakeholders, such as sales data, product information, manufacturing details and logistics information. Owing to outsourced services and distributed data sources, this process is cumbersome and involves a potential risk of non-compliance. In many cases, traders involve third-party providers to handle the Customs declaration process.

Blockchains can help collect all the information required from ordering, preparing and shipping the products in a common ledger. Ideally, this would require trade documents to be used in electronic format and different stakeholders in the supply chain to be part of a blockchain, allowing for provision of information from the most reliable sources. Customs could automatically pull the information required for a Customs declaration from the primary sources, which would have the benefit of improved data quality and immutability.

This would provide benefits on the trader side due to a significant reduction in the work needed to accurately assemble the pieces of information required for Customs processing, and on the Customs side by reducing the manual verification processes and hence the resources required to validate declarations. This would lead to faster Customs declaration processing and reduced end-to-end lead time, provided data is submitted in a standard format to minimize the need for reconciliation and facilitate processing.

The pilots carried out to date have not involved a sufficient number of stakeholders to allow for processing of Customs declarations via a blockchain platform, but some are working towards that end (see the Usyncro case study in the Annex to this Study Report).

### Inter-agency cooperation: exchange of information

There are several challenges in receiving advance electronic information and sharing it with other government agencies. There could be issues with data quality, data not being submitted in time, and potential inadvertent or deliberate mistakes in data due to it changing through multiple hands.

Blockchains can help overcome some of these challenges. Data sharing through “permissioned” blockchains (a distributed architecture) in a trusted and secure manner can help realize the vision of an end-to-end “data pipeline”. This kind of blockchain can be operated by supply-chain consortia, accessed and updated by all participants. Customs and other government agencies can secure accurate data, right from the source.

Given the global security environment, and the renewed focus on trade facilitation with the implementation of the WTO Agreement on Trade Facilitation (TFA), there is a greater need for different government agencies to cooperate more effectively. Blockchains may open up new pos-

sibilities for these different agencies, including Customs, to share information and resources by using a common distributed technical platform, especially in a Single Window environment[11] as well as new options for cross-border data exchange, such as between and among different Single Window or within a Globally Networked Customs (GNC) Utility Block (UB).[12] This could be a good case study for blockchain technology if all participants had a specific identifier code throughout the transactions, bearing in mind that one of the common challenges associated with this is that the entities are often given different names by different agencies.

*Blockchain technology can be very useful in terms of managing the identity of multiple stakeholders and customers in a supply chain (particularly in the e-commerce environment).*

In a growing digital economy, this technology can also help enhance cooperation between Customs and Tax authorities and the exchange of information between them, producing a more harmonized approach to revenue collection, audit and risk management, as well as to the issue of Customs valuation and transfer pricing.

### Electronic certification/verification of regulatory requirements

Traders must comply with a number of requirements, such as non-tariff requirements. There are increasing obligations for product certification in view of growing concerns about product quality and safety. Various licences, permits, certificates, and other authorizations (LPCO) may be required for Customs clearance, depending on the nature of goods and the related national regulatory requirements.

Several pieces of data are needed, including, for example, data concerning the certification of inputs to products (e.g. intellectual property rights (IPR) of products, IPR of inputs/constituents). Furthermore, a number of associated activities are carried out by various stakeholders such as certifiers, laboratories, producers, regulators and consumers. But often this information is not shared between all of the stakeholders concerned, leading to an iterative process of information gathering and carrying out the necessary certification and verification.

Blockchains can help overcome some of these challenges through holistic product lifecycle data management. The community of producers, laboratories, logistics players, regulators, and consumers can all join hands on a blockchain, providing a shared provenance, testing, certification, licensing, etc. with all relevant actors having full access to all related information.

Furthermore, the blockchain can enable the implementation of electronic certification of LPCO, such as e-Phyto certificates and e-Certificates of Origin (e-CoO) in a more efficient, secure and trusted manner. It could ensure that a certificate is issued appropriately, and signed properly and digitally by a valid regulatory/issuing agency, and at the same time could also prevent any alteration/manipulation of the content or misuse of an e-certificate by a third party.

We have already seen a significant number of projects that are aimed at implementing electronic certification and their validation, such as in the case of e-Certificates of Origin.

### Identity management

Blockchain technology can be very useful in terms of managing the identity of multiple stakeholders and customers in a supply chain (particularly in

11 http://www.wcoomd.org/en/topics/facilitation/instrument-and-tools/tools/single-window-guidelines.aspx
12 http://www.wcoomd.org/en/topics/facilitation/activities-and-programmes/gnc.aspx

the e-commerce environment). By moving away from centralized data management, it gives users control over their identity (known as self-sovereign identity) and enables them to limit the sharing of identity data to what is strictly necessary. Blockchain enables more secure management and storage of digital identities. It also presents interesting opportunities to facilitate the verification and management of identities across borders and offers concrete advantages for the implementation of mutual recognition agreements on AEO, for example, as the Cadena and bconnect projects in Latin America demonstrate.

### Revenue collection

Blockchain technology could enable any intermediary in the supply chain to collect revenue on behalf of governments, potentially allowing duties and taxes to be automatically transferred to the respective authorities using smart contracts. This could be useful when implementing new models of revenue collection on low-value and small shipments (e.g. vendor collection or intermediary collection) in the e-commerce environment.

Lack of transparency along the supply chain causes a number of concerns, including that the prices paid might be an inaccurate reflection of the true value, with repercussions on revenue. The greater transparency in, and traceability along, the supply chain that blockchain enables could help address issues of undervaluation and misdeclaration.

*Blockchain could prove the provenance of data, reduce fraud, and enhance visibility in the supply chain, for example by providing access to the commercial documents, starting with the initial purchase order between the parties.*

### Compliance management

Blockchain could prove the provenance of data, reduce fraud, and enhance visibility in the supply chain, for example by providing access to the commercial documents, starting with the initial purchase order between the parties.

Blockchain can help mitigate and eliminate risks around food security, conflict minerals, counterfeit goods, forced and child labour, corruption and so forth. Furthermore, it can assist in IPR management, providing transparent processes in the registration of IPR, associated authorizations, enforcement, and taxation issues.

### Post-clearance audit

Another potential case study of the blockchain is in the audit of Customs declarations and associated transactions and documents, in particular system-based holistic audit with an opportunity to look into each and every transactional trail (as needed).

**Prerequisites to take into consideration**

To enable the future use of this technology by Customs, including the associated requirements in terms of investments, resources and capabilities, there is a need firstly to become familiarized with the technology, and then to explore whether and for what purposes it could be used, as well as identifying the minimum data needed for the various regulatory processes. A dashboard is needed to access the data; this could be connected to the blockchain platform through the API to allow Customs and other agencies to pull the required data. This could offer unparalleled confidence about the provenance of data and enhanced visibility in the supply chain, for example by accessing the commercial documents starting from the initial purchase order.

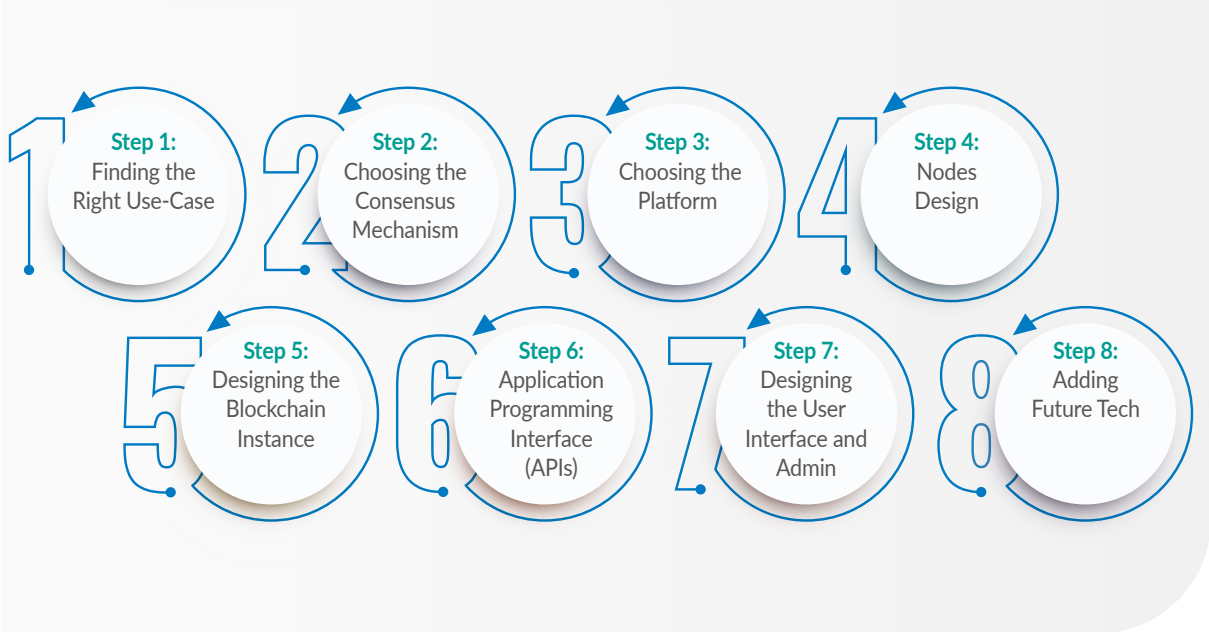
The WCO and the WTO will continue monitoring related developments on how the industry is using blockchain to provide guidance to Members and help them to prepare themselves, depending on their strategic imperatives and priorities.

As for the use of blockchain as an alternative payment solution, there are various blockchain-enabled payment solutions (the most well-known being Bitcoin). These solutions were designed to be equivalent to cash - completely decentral-

ized and anonymous monetary exchanges. These features could be easily exploited by criminals to move money around. In this context, understanding these unregulated currencies and how they work is important from a risk-management point of view. However, other electronic payment solutions are being built on blockchain that are not anonymous. Various banks and money transfer organizations are looking at using blockchain technology to create electronic payment solutions with a robust regulatory framework, in which the identity of an individual or company is meticulously authenticated. This has several benefits: for example, the blockchain could facilitate, in a couple of minutes, the negotiation of credit, a process which normally takes around two to three days. An increasing number of trade finance projects also leverage the blockchain technology. Most major banks involved in trade finance and a large number of fintechs and start-ups are developing blockchain-based solutions to facilitate trade finance processes like letters of credit, open account transactions, or supply chain finance.

Blockchain is essentially a network, rather than a stand-alone IT system. Therefore, implementing blockchain for Customs may mean that Customs participate in an existing blockchain applications, or create an initiative to introduce a new blockchain app.

*Figure 6: #8 Steps to build a blockchain solution*



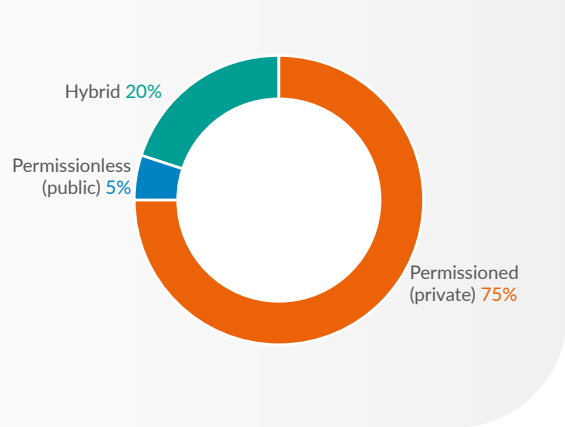

*Source: Entrepreneur Europe*[13]

13 *Entrepreneur Europe, 9 September 2017: https://www.entrepreneur.com/article/300077*

## C. Implementation by Customs in 2021

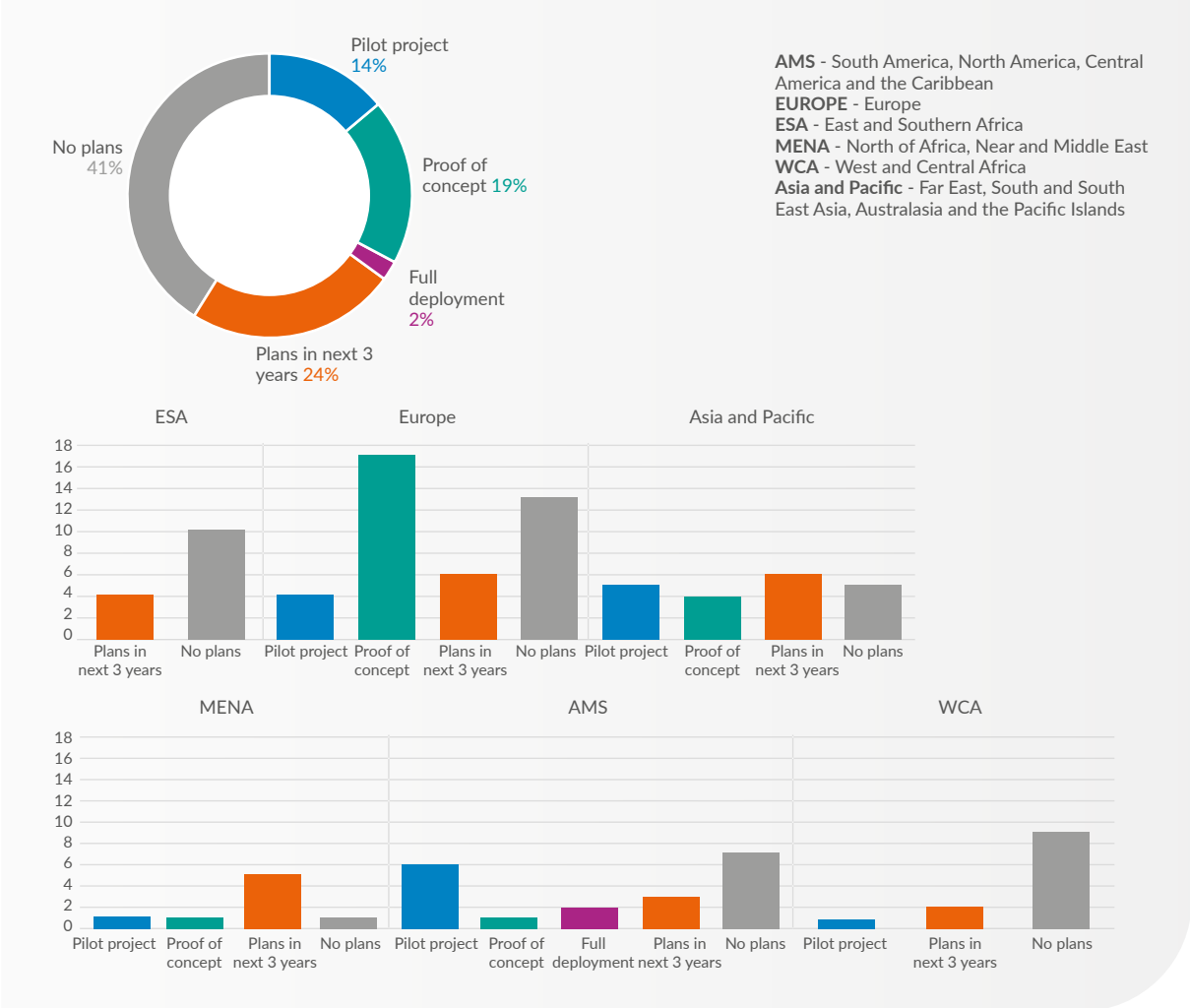
According to the results received through the WCO's 2021 Annual Consolidated Survey and the WCO-WTO paper "The Role of Advanced Technologies in Cross-border Trade: A Customs Perspective", blockchain/DLT is still in an experimental phase for Customs, with around a third of Customs authorities who responded testing it through proofs of concept (22 Members) and pilot projects (15 Members) using mainly private (permissioned) blockchains, while only two Customs administrations (Argentina and Uruguay) have reported a full deployment of this technology. Twenty-six Customs authorities have plans for this technology in the next three years, while another 45 Members have indicated that they have no plans in place yet.

*Figure 7: Types of blockchain in use*




*Note: Total respondents numbered 44.*

*Figure 8: Stage of adoption of blockchain*




*Note: Total respondents numbered 110.*

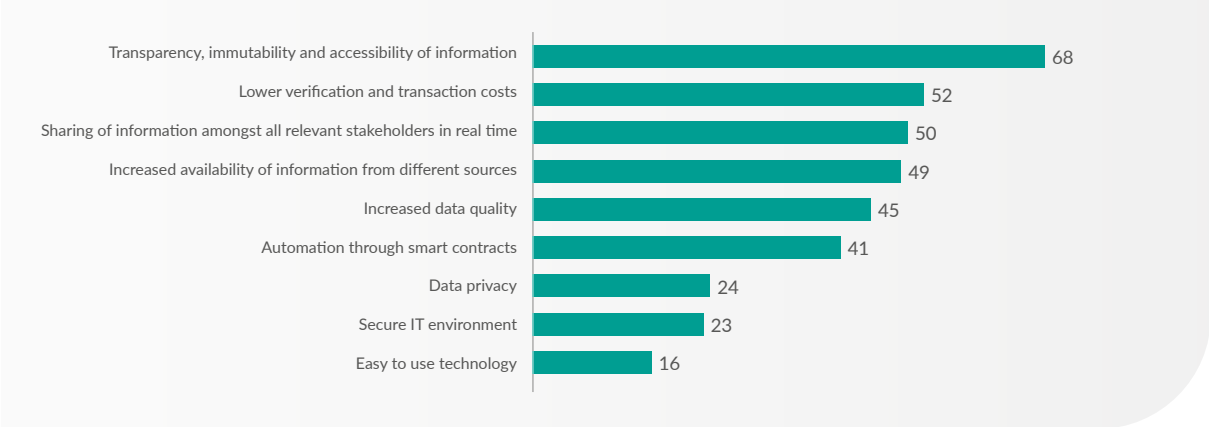
## Benefits and challenges

Members have expressed the hope that the use of blockchain will allow for better transparency, immutability and accessibility of information, and data quality, as well as the sharing of relevant information on border management procedures among all stakeholders.

However, a lack of expertise and good practices, as well as associated costs, are currently posing the biggest challenge to its introduction. Other reasons that could hinder the success of its full deployment could be a lack of standardized datasets used by government agencies and economic operators, a lack of efficient governance systems, and the potential for a proliferation of different blockchain solutions that are not interconnected.

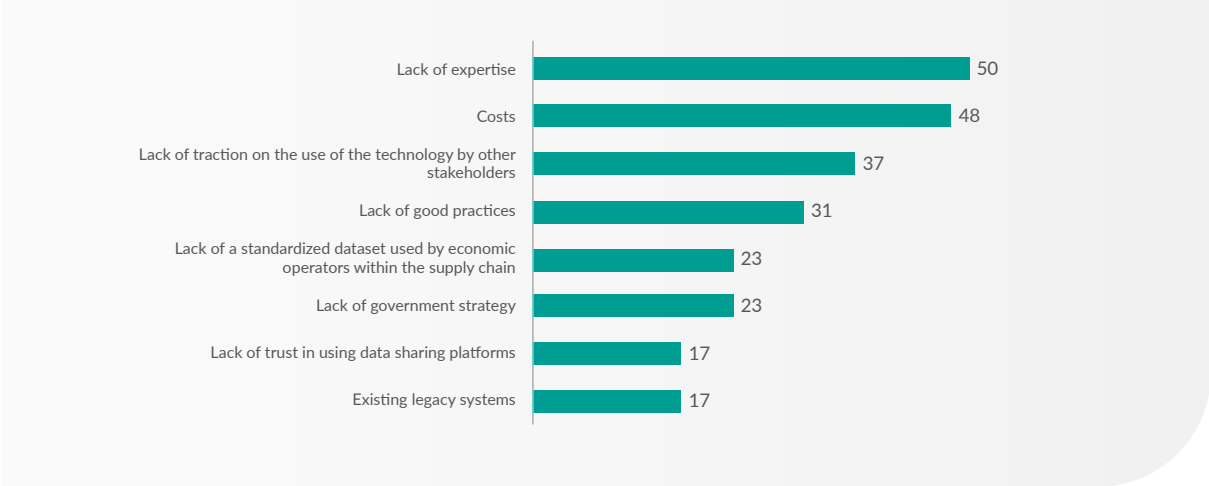
Despite a certain initial hesitancy, Customs administrations are reasonably optimistic concerning blockchain's potential; indeed, through blockchain, they hope to achieve greater efficiency and reliability in the areas of risk management, revenue collection, and trade facilitation. They are also coming to see the importance of partnering early with industry to ensure that the projects realize the benefits of the use of blockchain technologies in the trading environment, while at the same time addressing the barriers to this.

*Figure 9: Main benefits of introducing blockchain*




*Note: Total respondents numbered 87.*

*Figure 10: Main obstacles to adopting blockchain*




*Note: Total respondents numbered 95.*

*Box 3: Other common general concerns raised*

Many issues need to be discussed in view of the challenges in bringing blockchain technology into practice. These issues will still need to be looked into as part of the many ongoing pilot programmes. They include questions relating to security and privacy, for example. Each ledger is cryptographically secured so that people are prevented from tampering with current and past transactions. This kind of tamper-proof transaction record has become a source of trust in all the transaction history data embedded in a particular computerized network. Unlike cryptocurrencies (represented by Bitcoin), whose owners do not behave as individuals within the network, other kinds of blockchain applications are not immune to the possible outflow of personal or confidential information. In the words of a Deloitte report, many such applications "require smart transactions and contracts to be indisputably linked to known identities, and thus raise important questions about privacy and the security of the data stored and accessible on the shared ledger". In theory, blockchains have a notable security flaw: if more than half of the computers working as nodes to serve the network tell a lie, the lie will become the truth. This is called a "51% attack" – the potential defect of blockchains, inter alia, of Bitcoin – that could occur particularly in the process of "mining". More specifically, when the majority of the network's computing power has been taken over by an attacker or a group of) attackers, it is prevented from spotting and rejecting a fraudulent version of a public ledger.

Another concern relates to the decentralized nature of public blockchains; the network lacks a centralized overview function and therefore has no effective trouble-shooter that will work in the event of a contingency, thus reducing the resilience of the overall system. In other words, each participant could suffer directly from external shocks. This is less of an issue in the case of private and consortium-permissioned blockchains whose participants are known and whose governance rules have been agreed as part of the design of the platform.

Another often debated issue is the question of scalability. Public blockchains like Bitcoin are often criticized for their lack of scalability due in part to the consensus protocol used to validate the blocks. New generations of public blockchains, such as Cardano, are trying to address this issue. It is also worth noting that because they are more centralized, private blockchains do not present the same scalability challenges. Ultimately, a choice often has to be made between scalability, decentralization and security. This is what Vitalik Buterin, the co-founder of the Ethereum blockchain, called the "blockchain trilemma", the improbability of a blockchain obtaining all three of these three properties at the same time. Improving one of these three aspects would mean that the other two are likely to be compromised to some degree.

Interoperability is another issue that needs to be resolved. In the context of supply chains, blockchain is expected to bridge different supply chain parties and processes to increase the overall supply chain efficiency. The proliferation of blockchain networks that use different distributed ledger technologies and are governed by different rules has led to digital islands.

## Areas of implementation

Customs authorities are involved in a number of projects and Proofs of Concept (PoCs) that are intended to bring improvements in the following areas: (i) information exchange and interoperability at national and international levels (including at the level of Customs Unions); (ii) the development of international Single Window interconnectivity, ensuring proper validation of certificates (including certificates of origin, quality, sustainability, non-toxicity); (iii) information sharing on AEOs and within e-commerce environments; and (iv) ensuring access to logistics-related information in view of tracking and tracing goods along global supply chains. Numerous advantages have been observed by administrations taking part in these pilot projects, such as expedited processing, better data quality, transaction transparency, enhanced targeting, and easier access to importers. In other cases, however, Customs sometimes lack an incentive to join blockchain projects in cases where there are insufficient numbers of participants to provide the information required.

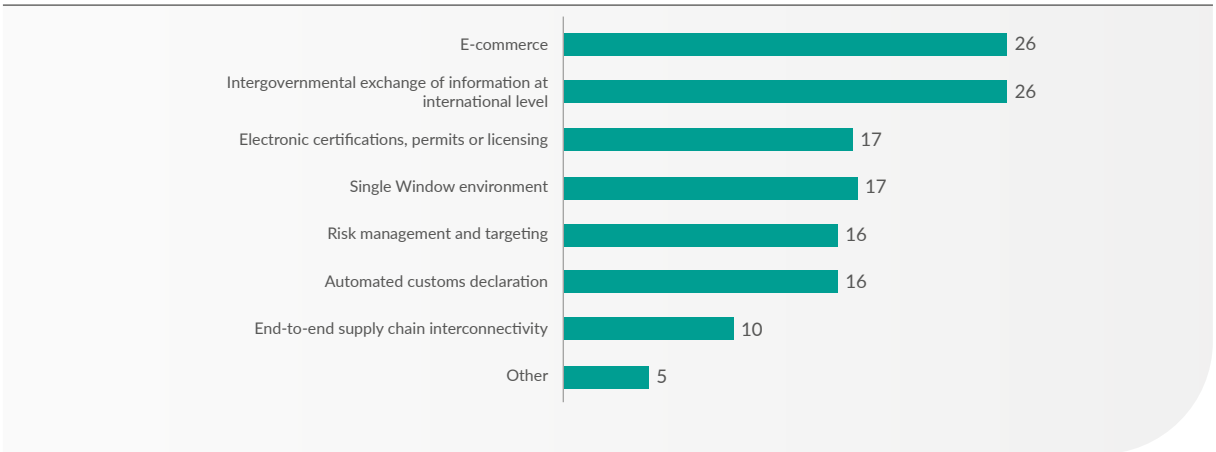
## Ongoing projects

Most of the blockchain projects are being implemented in Europe, Asia/Pacific, and the Americas and Caribbean regions. Some of these projects are elaborated in more detail in the Annex to this Study Report.

In the European region, blockchain is used for the purposes of VAT collection, protection of geographical indications, and certification of product origin. Several ongoing pilot projects and PoCs are being tested.

For example, the EU Member States are exploring the use of blockchain for the sharing of VAT information between taxation and Customs authorities through the SEED-on-Blockchain project coordinated by the European Commission (DG TAXUD). Furthermore, blockchain can automate VAT payments via smart contracts, including payment of VAT to the tax authorities and from the tax authorities to a company, thus accelerating VAT collection and reducing payment delays.

*Figure 11: Project areas*




*Note: Total respondents numbered 44.*

In June 2021, Italy launched the blockchain project TRICK which provides for the certification of high-quality manufacturing products, with the objective of placing on the market products that have already been certified at various levels, from sustainability certification, with materials deriving from a sustainable economy, to chemical certification of non-toxicity, to certification of origin of the goods.

Georgia has launched a project for issuing and validating preferential Certificates of Origin using a blockchain.

In the Asia/Pacific region, blockchain technology is used to exchange Customs declarations and documents, as well as logistics-related information with a view to tracking and tracing goods/parts and transport units throughout global supply chains.

China and Singapore Customs are cooperating in developing an International Trade Single Window Interconnection Consortium Blockchain, exchanging information on clearance and logistics/cargo status, to further leverage the role of a Single Window in improving the port business environment and trade facilitation.

Hong Kong Customs is conducting a PoC study in applying blockchain to a licence management system, while Malaysia is piloting the use of blockchain to provide more efficient AEO services.

A blockchain PoC was conducted under the auspices of the Singapore-Australia Digital Economy Agreement to achieve document interoperability for cross-border paperless trade, allowing for the issuance and verification of Certificates of Origin, in accordance with an interoperability framework, the so-called TradeTrust framework.

In the Americas and Caribbean region, blockchain is to a large extent used to facilitate information exchange on AEOs, but there are other case studies as well.

The CADENA project, implemented by Customs administrations of Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico and Peru, and with the support of the Inter-American Development Bank (IDB), allows the use of blockchain as a registration system for AEOs. CADENA is a project using the LACChain ecosystem which provides an infrastructure enabling the development of different blockchain-based applications/projects in Latin America and the Caribbean region. LACChain represents a global public-private alliance promoted by the IDB Innovation Laboratory.

Another project aimed at exchanging information on AEOs is Mercosur's bConnect Project, which deploys Blockchain Private Hyperledger Fabric 1.4. The following Member countries are part of the bConnect system: Argentina, Bolivia, Brazil, Paraguay, and Uruguay.

Guatemala is working on the development of a new maritime and air dispatch model, which is based on blockchain technology, taking as a reference the Port Community Systems (PCS). The project aims to automate exports in the Customs Terminal in Sea Port Application Performance Management (APM), and to develop web services for the exchange of information with other terminals.

*Numerous advantages have been observed by administrations taking part in these pilot projects, such as expedited processing, better data quality, transaction transparency, enhanced targeting, and easier access to importers.*

United States Customs and Border Protection (CBP) conducted the North American Free Trade Agreement/Central America Free Trade Agreement (NAFTA/CAFTA) PoC in September 2018, which tested the application of blockchain technology for the entry/import summary declaration submission process for NAFTA/CAFTA entries. Furthermore, in September 2019, CBP conducted the Intellectual Property Rights PoC, which tested a blockchain technology in facilitating shipments based on known licensing relationships.

In the MENA region, blockchain is used to exchange Customs declarations and documents, such as Certificates of Origin.

Moroccan Customs has launched a cooperation project with DHL and the German International Cooperation Agency with a view to developing a platform relying on blockchain technology for collecting the data of each party to an international transaction (traders, express mail service, Customs, other stakeholders) and sharing it.

*Customs authorities are involved in a number of projects and Proofs of Concept (PoCs) that are intended to bring improvements in many areas.*

The United Arab Emirates and Dubai Customs have developed a cross-border e-commerce platform based on blockchain technology to facilitate and track e-commerce movements, within the network of Customs, e-commerce companies, ports, couriers, third-party logistics, free zone authorities, and permit-issuing authorities.

In the ESA region, one Member (Mauritius) has reported that it is discussing with potential suppliers the implementation of a project for tracking Certificates of Origin using blockchain technology, while in the WCA region, Customs authorities are waiting for the relevant capacity and knowledge to be developed before moving forward with a blockchain agenda.

A number of Customs administrations globally have partnered with the TradeLens consortium, already mentioned above, in order to pilot the use of its platform based on blockchain technology. These are: Azerbaijan, Canada, China, Indonesia, Jordan, Malaysia, the Netherlands, Russia, Saudi Arabia, Singapore, Thailand and Ukraine.

Canada Border Services Agency (CBSA) provided feedback on the pilot projects carried out with TradeLens. They found that, while there was an increase in the visibility and traceability of a container, additional data was limited or not available. As per the CBSA's assessment, the platform currently lacks a useful volume of participants (specifically cargo owners/vendors, Customs brokers, and maritime freight carriers). Due to the limited number of participants involved in the platform at the time of the CBSA evaluation, and the fact that the information input by stakeholders was voluntary (that is, no legal or regulatory obligations), the amount of content and data quality was inconsistent and relied entirely upon the submitter's technical ability to provide such information and to do so at their own discretion. Also, while CBSA had an interest in the movement of containers and their origin provided by TradeLens, it was not truly the information that was required for it to conduct its core mission. Border management required more information than was currently available in TradeLens, such as importer declarations and manifest information, that goes beyond what is required to enable the movement of goods.

# 2. Internet of Things (IoT)

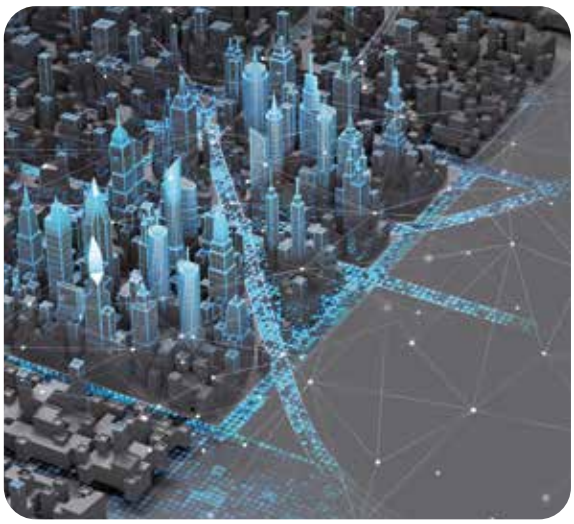
## A. What is IoT?

The Internet of Things, or IoT, is the internetworking of physical devices (also referred to as "connected devices" and "smart devices"), vehicles, buildings and other items embedded with electronics, software, sensors, actuators, and network connectivity which enable these objects to collect and exchange data. Simply put, the IoT transforms physical objects into smart devices to communicate, as well as interpret, information from their surroundings. It is used to make our lives more comfortable, and our businesses more efficient and less costly.

Although it has not yet achieved mainstream acceptance, over recent years the IoT has been gaining more traction. Connected machines, such as ATMs and airline check-in machines, have been in use for many years now. But new and novel devices, and many ordinary objects, are now being reinvented with digital sensing, computing and communications capabilities. The IoT has incorporated many kinds of physical goods (e.g. home appliances, security cameras and garbage containers) into big data applications. The practical examples of IoT deployment range from smart fitness bracelets to driverless vehicles.

The IoT has become a powerful force for business transformation, and its disruptive impact is already being felt across all industries and all areas of society. This sudden expansion boosts the economic impact of the IoT as consumers, businesses, city authorities, hospitals and many other entities find new ways in which to exploit the technology. Statista[14] estimates that, by 2025, the IoT will be made up of over 30 billion devices worldwide (more than four devices per person).

Smart devices for household applications may be the main focus of IoT, which will offer a smart home where all electronic devices are connected, capable of communicating with each other and sending information whenever necessary.



For example, sensors in the walls will be able to detect your presence in the room and control the air conditioner's temperature. Smart sensors attached to the door will help to open and close the door once someone reaches its vicinity. They will also be able to trigger some actions such as turning the lights in the room on or off or adjusting the airflow to the room. Smart water-level sensors will be able to monitor the use of water and control the flow of water in an appropriate manner, etc.

A smart city uses technology to improve the efficiency of its services. IoT allows city officials to interact directly with the community and the city infrastructure, and to monitor what is happening in the city, how the city is evolving and how to enable a better quality of life. Through the use of sensors integrated with real-time monitoring systems, data is collected from citizens and devices and then processed and analysed.

Ultimately, the objective of smart cities is to increase efficiency and reduce costs and consumption. Smart city applications are also being developed to manage urban flows and allow for real-time responses. A smart city may therefore be more prepared to respond to challenges.

14 *Global IoT and non-IoT connections 2010-2025 | Statista*

A smart city can include energy and water management, smart lighting, predictive life maintenance for elevators, traffic monitoring etc. Examples of Smart City technologies and programmes have been implemented in Milton Keynes, Southampton, Amsterdam, Barcelona, Madrid and Stockholm, and in China. In Singapore, a Smart Nation Sensor Platform will be implemented to improve municipal services, city-level operations, planning and security, for a smarter, greener and more liveable city.

Now we are able to connect our cars with smartphones and specially designed applications can be used to perform certain tasks. Many sensors in the car collect information and send it to a service team or manufacturer's database. This data will help manufacturers to track and monitor how individual units perform. It will also help the design team to continuously improve their product. IoT can also be used in other areas such as healthcare, smart farming, and wearable technology (smart watches) etc.

*The IoT has become a powerful force for business transformation, and its disruptive impact is already being felt across all industries and all areas.*

However, there are risks. Each device which is connected to the IoT increases privacy and security concerns. These range from hackers stealing our data and even threatening our lives to how corporations can easily inadvertently expose or misuse private data we provide them with. Hackers could potentially take control of cars and remotely accelerate or decelerate them, or take control of baby monitors or other home appliances etc.

The fundamental security weakness of the IoT is that it increases the number of devices behind the network's firewall. Fifteen years ago, most of us only had to worry about protecting our computers. Ten years ago, we had to worry about protecting our smartphones as well. Now we have to worry about protecting our car, our home appliances, our wearable devices, and many other IoT devices.

Companies pressured to get their devices out in the market quickly end up compromising on security. Even if they offer firmware upgrades for a while, they often stop when they focus on constructing the next device, leaving customers with slightly outdated hardware that can become a security risk, or suffer compatibility issues. Furthermore, connecting large numbers of new devices to the Internet can create serious bottlenecks in telecommunication systems.

## B. Links between IoT and other technologies

There is a very logical link between the different disruptive technologies which needs to be kept in mind when considering how one or more of these technologies can be used to support a certain business. The latest technologies are rarely unrelated, and generally support each other in one way or another. For example: mobile technologies are incorporating more and more artificial intelligence (AI) and machine learning to improve client service; IoT relies to a large extent on the Internet and cloud computing; AI relies on IoT data, especially for real-time responses (e.g. for autonomous vehicles), the execution of smart contracts also relies on IoT data, etc. Some interesting examples are provided below.

### IoT and robotics

IoT can prove very advantageous in supporting robotics. For example, Asea Brown Boveri (ABB) has been finding ways to integrate all of the sen-

sors and devices on a manufacturing shop floor to improve all areas of their operations, including reducing the downtime of robots, improving the reliability of systems and optimizing processes.

There are great benefits when every robot is able to store and analyse its own usage data, then is able to communicate that data smartly to other connected devices. For example, it means that ABB does not have to schedule the maintenance of a robot by a simple, old- fashioned "after 10,000 hours of uptime", which might be overly conservative. Instead, the robot itself can monitor its own actual usage and report on its performance. ABB can schedule maintenance of the robot at the perfect time to avoid interfering with its operations, by looking at when the robot is actually used most. It can also mean that potential problems are addressed in a timely manner.

The recent upsurge of the "smart" or "connected factory" has become a modern solution to rising productivity needs, where the technology employed seeks to connect data, people, and machines into a coherent system. These new systems have, so far, shown an increase in labour productivity, factory capacity utilization, and production by offering new data-driven insights as to how factories and suppliers can optimize their processes in near real-time or real-time. Alongside IoT and robotics, artificial intelligence and machine learning (cognitive process automation) are playing a key role in what has been called the Fourth Industrial Revolution. As a 2019 Deloitte study revealed, "85% of study respondents believe smart factory initiatives will be the main driver of manufacturing competitiveness in the next five years, and 83% say they will transform the way products are made in five years."[15]

In 2014, KUKA integrated with Microsoft's Azure IoT platform to create a "connected factory" of 60,000 devices and 259 robots. Over the last few years, Amazon Web Services (AWS) has introduced several cloud-based automation and robotics services, namely RoboMaker in 2018 and IoT RoboRunner in 2021. AWS IoT RoboRunner service provides clients with the capacity to build and deploy applications that manage their robot fleets and optimize tasks carried out by different devices.[16] These applications show that IoT concepts can be well and truly integrated into industrial robotics.

### IoT and biometrics

With the growth of IoT and biometric technology, authentication is being completely reimagined in smart homes, smart cars etc. Passwords and PINs are easily forgotten or guessed, but no two people have the same biometric indicators. Enterprises across sectors are looking to biometrics for their authentication needs. People always have their fingerprint, face or iris with them. The latest smartphones, as well as many new desktop and laptop computers, already contain embedded biometric sensors.

However, biometric authentication introduces a major concern for companies: that of protecting biometric data. Traditionally, biometric data is stored in one location and if someone wants to authenticate access to a system they provide their unique information, which is then compared to the database. There is a core defect with this, however; it creates a central repository of sensitive data that is a valuable target for malicious activity. But there are solutions to such issues. For example, biometric tokenization operates similarly to the form of encryption commonly used to secure payment card numbers and other sensitive information. When implemented properly, biometric authentication can be used for a connected home, connected car, and smart locks.

15 *Wellener, Paul. 2020. How Smart Factories Can Ignite Productivity. Wall Street Journal, https://deloitte.wsj.com/articles/how-smart-factories-can-ignite-productivity-01580760126*

16 *https://aws.amazon.com/blogs/aws/preview-aws-iot-roborunner-for-building-robot-fleet-management-applications/*

### IoT and virtual reality

Virtual reality (VR) and IoT share a similar basic philosophy and purpose. Both involve the merging of the physical and the digital world. By combining VR and IoT, two innovators have created what could be the next step in how we communicate with each other over long distances. The two products, Empathy VR and the OdenVR Telepresence Robot pair a virtual-reality head-mounted display with a highly mobile remote-controlled robot. The ability to both look and move freely within a real-world space creates a very strong illusion of actually being present. These new capabilities have also led to virtual-reality chat rooms where users can roam around a digital landscape via an avatar they create and customize. This can be seen with new collaboration platforms like Spatial, which promises the use of augmented and virtual realities to turn physical rooms into 3D workspaces using headsets like Microsoft's HoloLens and the Magic Leap One.[17]

*The fusion of IoT and AI includes smart sensors (or intelligent sensors) which provide real-time data and feedback information fulfilling a number of different capabilities.*

One of the most dramatic confluences of VR and IoT has been the technologies used in the healthcare field. Robotic-assisted surgery is already in use across the world using innovations like the da Vinci surgical system. Using a tiny camera and precision surgical tools, the da Vinci system allows a surgeon to perform minimally invasive surgery from a control console. By inserting the camera and tools through a comparatively small opening in the body, the surgeon can gain a full view of the operating area without subjecting the patient to the trauma of a large incision.

New advances in the field of robotics and communication technology have also offered a glimpse of the revolutionary changes that will affect several service industries. Technologies facilitating telepresence and telerobotics will enable users to remotely operate complex machinery, namely robots, to fulfil highly skilled and specialized tasks. While the da Vinci surgical system mentioned above requires a surgeon to directly operate the system, telesurgery capabilities will allow surgeons to perform operations in complicated or out-of-reach areas such as conflict zones, space stations, or (remote) areas lacking qualified/experienced professionals.[18]

### IoT and artificial intelligence & machine learning

IoT relies on sensors across assets and goods, which transmit signals to core systems. This results in a massive amount of data being recorded and analysed every millisecond, and businesses need the right systems to understand it. The smartest businesses use this data in combination with AI and ML to enable evidence-based prediction of what will be needed, when and where.

The fusion of IoT and AI includes smart sensors (or intelligent sensors) which provide real-time data and feedback information fulfilling a number of different capabilities:

- Predictive: real-time data can be analysed to determine when a large piece of machinery or equipment will break down, enabling the failure to be prevented through proactive intervention.
- Prescriptive: intelligent sensors can suggest immediate action sometimes in remote areas, thus avoiding outages and even disasters. For example, sensors on railway tracks can warn the control centre of any track failures.
- Adaptive/autonomous: continuous data feeds from sensors can enable systems to learn the right actions to take autonomously. For example, in a healthcare context, blood glucose sensors can automatically change the level of insulin delivered in response to patient needs. Similarly, monorail systems in many airports and cities run autonomously without any human drivers.

17 https://www.vox.com/recode/2020/9/15/21434946/augmented-reality-future-remote-work-spatial-zoom-calls-feel-like-real-life
18 WTO 2018 World Trade Report, p. 87

### IoT and blockchain technology

One of the key links in this case is that blockchain technology can improve the security of information in the IoT and reduce costs. Namely, with blockchain technology, IoT data can be managed without setting up a complex and expensive centralized IT infrastructure where devices rely on a central cloud server to identify and authenticate individual devices. With every legitimate node being registered on the blockchain, devices will easily be able to identify and authenticate each other without the need for central brokers or certification authorities, and the network will be scalable to support billions of devices without the need for additional resources. IoT devices will be able to interconnect in a reliable way while avoiding threats such as device spoofing and impersonation. On the other hand, smart contracts often use data generated by IoT devices to trigger contract execution.

## C. Current use in logistics and supply chain management

Where trade in goods is concerned, stakeholders such as manufacturers, shippers and logistics operators have focused on ensuring that the vast array of data, ranging from personal transaction history to the location of containerized goods, can be put to practical use, with a view to providing quality service and enhancing the connectivity to be reflected in the supply chain. A survey by GT Nexus and Capgemini found that 70% of retail and manufacturing companies had already started a digital transformation project in their supply chain and logistics operations.

Asset tracking has become extremely important in supply chain management. It gives companies a way to make better decisions and save time and money. IoT is used for monitoring the movement of goods in real time. This includes monitoring the position of the container, which can help voyage optimization. For instance, if there are blockages on a certain road, trucks could be rerouted to save time and money.

Fresh vegetables might last a week with no temperature variation, but not if they warm up for a few hours. According to the Food and Agriculture Organization of the United Nations (FAO), up to one third of food perishes in transit every year. Refrigerated containers (reefer containers) carrying perishable goods are equipped with sensors measuring temperature, light and humidity, for example, which will contribute to food safety and prevent/reduce spoilage. The changes in temperature can trigger alerts that will be followed by mitigation action.

Shipping companies like Maersk have partnered with telecommunications companies to develop a real-time remote container management (RCM) system capable of transmitting performance data in order to cut down on lengthy inspection processes.[19] Regarding reefers, these RCM systems relay essential information such as temperature, location, and power supply every hour, which, in turn, allows operators to determine what type of inspection will be required upon docking. This has yielded several operational efficiencies and savings, namely through better asset usage and performance, and faster turnaround times. Thus, through the implementation of smart sensors, digital management systems, and data analytics, logistics companies are now expanding their services from offering the purely physical transportation of trade to also providing value-added advisory services to their clients.[20] Additionally, as trade information becomes digitized and more accessible, special apps can help the customer receiving the goods verify whether the arriving parcel is correct, by using a bar code reader.

IoT has contributed to the growth of e-commerce. It has transformed how people buy – through Omnichannel sales and superfast shipments. Companies such as Amazon and Alibaba are able to deliver within one hour of ordering, and rely on the technology to move every item with accuracy and on time. Amazon warehouse robots show just how much technology and devices/equipment connected through the Internet can contribute to the speedy delivery of goods. Profit-driven companies are taking the most from the technologies

19 *For more information, refer to the WTO World Trade Report 2018*
20 *WTO World Trade Report 2018, p. 67*

to ensure even more profit. Some postal services use smart mailboxes in remote areas to check whether they contain anything and thus avoid a wasted journey for collection.

Asset tracking is not new by any means. Freight and shipping companies have long used barcode scanners to track and manage their inventory. But new developments are making these scanners obsolete, as they can only collect data on broad types of items, rather than the location or condition of specific items. Newer asset-tracking solutions offer much more vital and usable data, especially when paired with other IoT devices.

Several new pieces of technology are already changing how logistics companies work. RFID (radio frequency identification) tags use radio frequency technology to provide data on items to which they are attached. Internet-connected trackers use long-range networks or Low Power Wide Area Networks (LPWANs) to let companies track specific items throughout their delivery journeys. In the same vein, satellite trackers provide location data on an item almost anywhere on the planet, even in areas that do not have mobile coverage.

Bluetooth, ZigBee and Wi-Fi are adequate for consumer-level IoT implementations. The need for a technology such as LPWAN is much greater in industrial IoT, civic and commercial applications. In these environments, the huge numbers of connected devices can only be supported if communications are efficient and power costs low.

Bluetooth tags and beacons offer tracking data in smaller, more confined areas, and are most often used in retail stores to monitor customer traffic and offer marketing messages to customers.

Finally, near-field communication (NFC) tags, based on RFID standards, allow workers to use their mobile devices as readers for the tags, which provides an advantage over RFID tags and readers.

## D. Potential use in Customs and border management

Suppliers and consumers are digitally connecting in real time. Big companies are using IoT to track their goods and improve customer service. The question is how can Customs and other border agencies plug into this network and benefit from this information, based on integrated supply chain management principles, to ensure that trade facilitation and security requirements in the movements across borders are met.

*Customs administrations would be able to focus on using analytical tools to identify high-risk and low-risk shipments and supply chains based on information collected through IoT technology.*

Disruptive technologies could make it possible to accomplish these two goals, but in order to succeed, the innovations must benefit both the private sector and governments in several different ways. Political leadership must see a match to public policy goals, and developers must see a profit opportunity in implementing such solutions. In September 2018, Singapore Customs launched the Networked Trade Platform (NTP), to give traders a one-stop interface that will enable them to interact with all business partners, stakeholders and regulators on trade-related transactions. Being an open digital platform, it allows service providers to develop new applications and foster innovation within the trade ecosystem.

Customs can work towards strengthening cooperation with certain stakeholders (shippers, carriers, forwarders etc.) that have employed IoT applications, with a view to promptly obtaining any information that corresponds to certain risk factors. Thus, Customs administrations would be able to focus on using analytical tools to identify high-risk and low-risk shipments and supply chains based on information collected through IoT technology.

As IoT is used in particular for monitoring the movement of perishable goods to avoid spoilage and loss, this information would help Customs and other relevant border agencies understand which shipments are more urgent in terms of release and clearance, and thus give them priority in release/clearance procedures. This would also help Customs ensure that health and safety concerns have been met, as information would be available on the temperature readings throughout the supply chain.

IoT is the underlying technology of so-called Smart Port Logistics which is operational in the port of Hamburg, for example. Due to a lack of space, the port operator had to increase efficiency and make sure that containers move swiftly in and out of the port. This means informing lorry drivers (or the railways) of the exact time of arrival of containers, for instance, so that they spend the shortest possible time in the port. Other major ports, like the Port of Rotterdam, have partnered with companies like IBM to develop their own IoT platforms capable of collecting and relaying vehicle, cargo, maritime and meteorological data to make their services more efficient. Through this data-driven initiative, the Port of Rotterdam is attempting to identify the optimal time and location for ships to dock and unload their cargo in order to speed up processing and minimize docking times. While these two European ports are modernizing their infrastructure and processing systems, other regions are also following suit, such as South Africa's Durban Port.

Logistics operators could prove to be very important partners in both trade facilitation and control, and inform the authorities of any suspicious occurrences in the supply chain. Using companies' track-and-trace solutions for Customs purposes could be a huge advantage.

IoT can help inform on the number of parcels arriving for clearance at a certain Customs post and on any potential delays. Artificial intelligence could

help identify, based on the number of staff, how long potential delays at the Customs post will be. It can also track down individual parcels and boxes in the shipment marked with serial numbers, which could speed up the process of singling out those which have been selected for physical inspection based on risk assessment.

A number of Customs administrations are monitoring the movement of cargo/shipments in real time, specifically shipments under duty suspension procedures, such as Customs transit. One example of such solutions is the Regional Electronic Cargo Tracking System (RECTS) deployed by Uganda, Kenya, Rwanda and the Democratic Republic of the Congo. Another IoT case study for Customs is the integration of various devices (X-ray or CT scanners, CCTV cameras, Automated Container Code Recognition (ACCR) and License Plate Recognition (LPR) devices and under-vehicle inspection systems (UVIS)) with the Customs information system for better risk management, greater efficiency of Customs clearance processes and improved analytics.

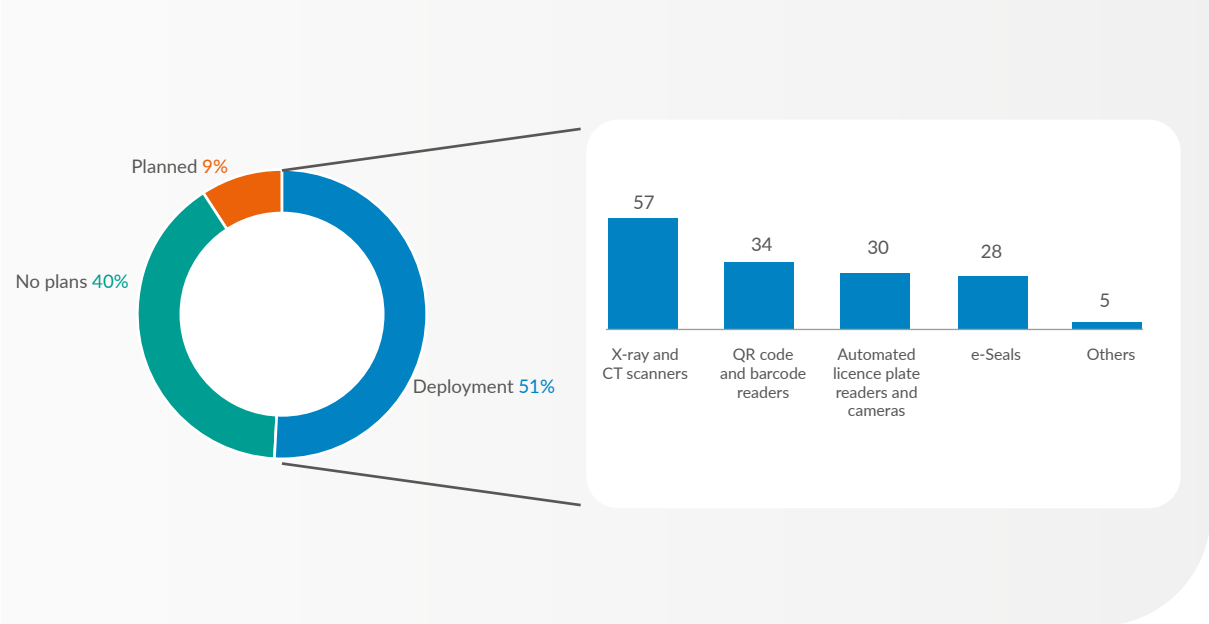
The fact that everything that is connected to the Internet or interacting with it can be geo-located is now an important new parameter which may also provide new opportunities to Customs.

## E. Implementation by Customs in 2021

According to the results received through the WCO's 2021 Annual Consolidated Survey and the WCO-WTO paper "The Role of Advanced Technologies in Cross-border Trade: A Customs Perspective", half of the respondents indicated that they use IoT in Customs business processes, and 9 per cent planned to deploy them. However, as many as 40 per cent had no plans to use the technology. Of the 72 respondents deploying IoT, the majority indicated that this was in relation to X-ray or computed tomography (CT) scanning, and significant numbers used QR code and barcode readers, automated licence plate readers and cameras, and electronic seals (e-seals).

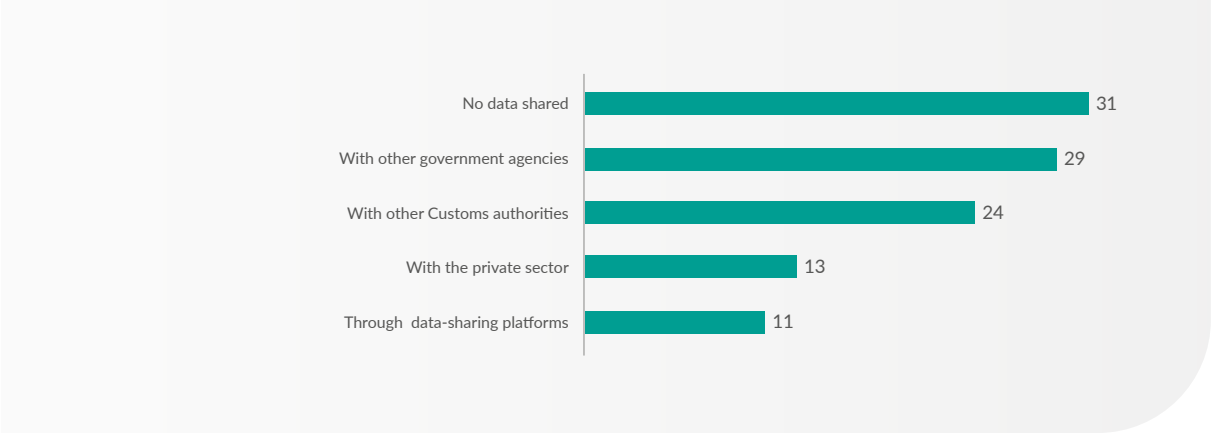

With regard to sharing information collected through IoT devices, 108 responses were provided by 78 Members, which means that some Customs authorities use multiple channels. For those who share information, the majority only share information with other government agencies and Customs authorities. A large number of respondents (31) do not share information with any stakeholders.

*Figure 12: Stage of adoption of the Internet of Things*




*Note: Total respondents numbered 94.*

*Figure 13: Sharing information with other stakeholders*

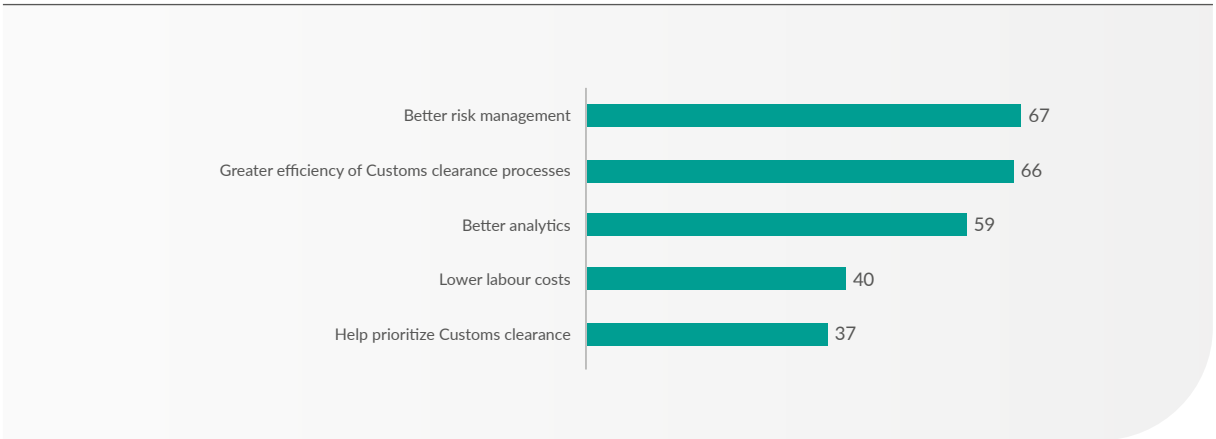



*Note: Total respondents numbered 108.*

## Benefits

The main benefit of IoT for Customs authorities is to enhance the volume and variety of data, which in turn helps to achieve improved risk management, greater efficiency in Customs clearance processes, and better analytics. One respondent mentioned the benefit of monitoring the integrity of transhipment cargo movement between entry and exit control points. Another emphasized the benefit of using IoT to standardize processes for the benefit of traders, enhancing port performance by reducing times for loading and unloading goods in port areas, linking innovative solutions already implemented by the Customs authorities, and reducing manual procedures to improve security and legitimate trade.

*Figure 14: Main benefits of introducing the Internet of Things*




*Note: Total respondents numbered 83.*

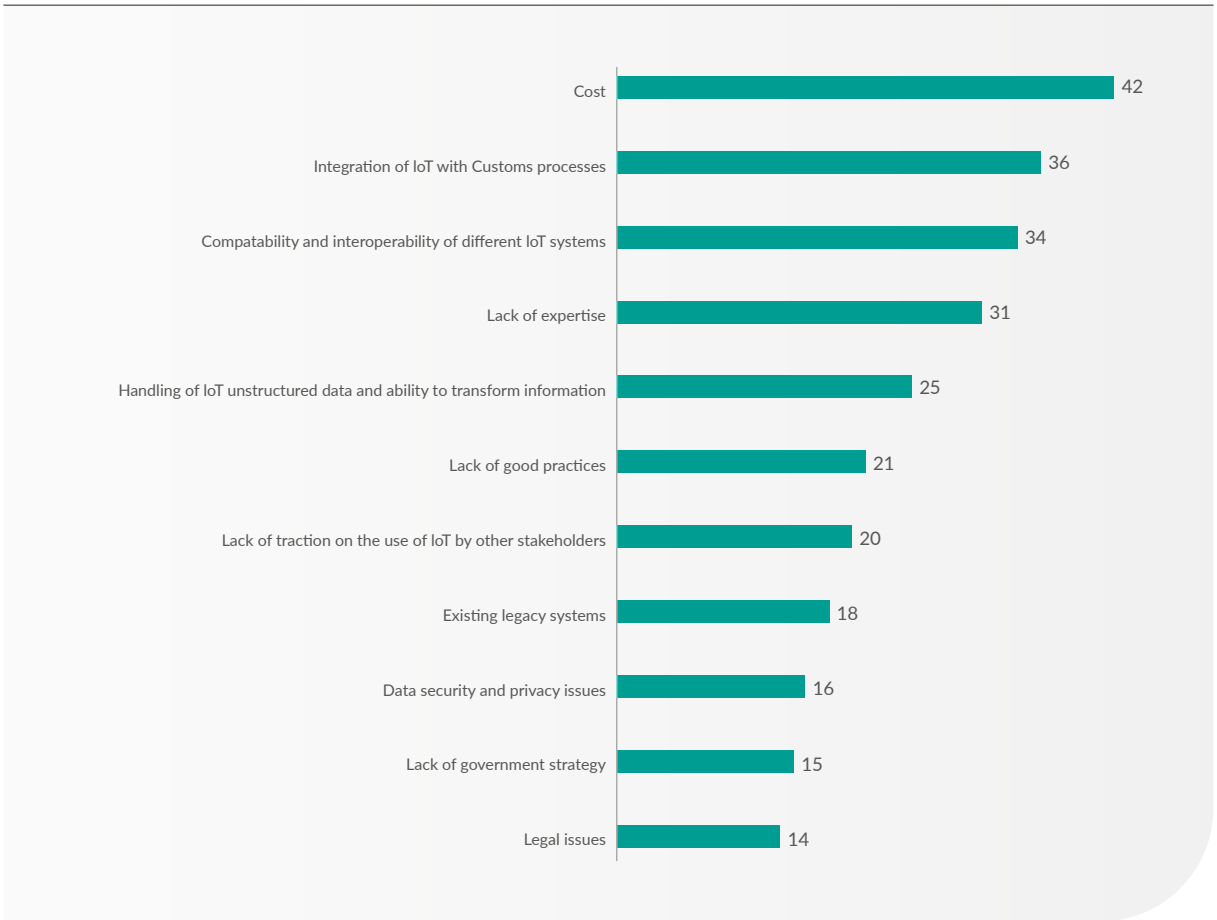
## Obstacles to adoption

Many respondents viewed the cost of introducing IoT solutions as a significant obstacle, along with the work involved in integrating IoT into established processes, and issues of compatibility and interoperability of different systems.

Having the necessary knowledge to introduce IoT is a significant obstacle. Respondents indicated a lack of expertise and good practices, and the challenge of handling unstructured data. Legal issues and data security and privacy were also mentioned.

Respondents also emphasized that if two or more neighbouring countries introduced IoT solutions, then they could all reap the full benefits across borders. However, not all Customs authorities are familiar with the technology, or able to introduce it; rather, there can often be resistance to change. The lack of infrastructure was another obstacle to a more profound uptake of IoT technologies.

*Figure 15: Main obstacles to adopting the Internet of Things*




*Note: Total respondents numbered 82.*

### Ongoing projects

All WCO regions have IoT deployment projects. Some of these projects are elaborated in more detail in the Annex to this Study Report.

In the East and Southern Africa (ESA) region, IoT is used to facilitate acquittal of transits through QR codes for example in Zambia. In Eswatini, the barcodes generated by the Automated System for Customs Data software (ASYCUDAWorld) are already one element in place to implement IoT. Another example of IoT deployment, also mentioned above, is the Regional Electronic Cargo Tracking System (RECTS) of Uganda, Kenya, Rwanda and the Democratic Republic of the Congo.

In the West and Central Africa (WCA) region, IoT is used to track cargo in transit through e-seals and barcode readers (e.g. in the Democratic Republic of the Congo).

The use of IoT is widespread in Europe, where CCTV cameras, licence plate readers, X-ray scanners and GPS tracking devices are quite broadly used and integrated with Customs processes at the national level, or even shared at the regional level. Other projects include the use of geo-fencing and telematics data for transferring information to Customs authorities through smart phones and apps to recognize border arrivals (e.g. in Switzerland).

The Baltic X-ray Images Exchange (BAXE) project implemented by Estonia, Latvia and Lithuania was designed to address different challenges such as the lack of interoperability of X-ray scanners produced by different vendors, and disparities in software and user interfaces. Since its adoption, 16 X-ray scanners in operation in Estonia, Latvia and Lithuania have been integrated into BAXE. The three countries exchange X-ray images, which are then analysed centrally in Latvia.

There is also an automated licence plate recognition system shared between the Baltic States and Poland, and IoT is utilized in the corridor-as-a-service (CaaS) pilot project to experiment with fully automating a border-crossing.

*The use of IoT is widespread in Europe, where CCTV cameras, licence plate readers, X-ray scanners and GPS tracking devices are quite broadly used and integrated with Customs processes at the national level, or even shared at the regional level.*

In Italy, the Customs and Monopolies Agency (ADM) is conducting a project to completely digitalize Customs procedures in Italian ports for goods transported by both rail and road. The project, which involves all the main port institutions, is based on IoT, with special readers providing information to authorized stakeholders. The advantages for operators include fewer requirements and submissions.

The Far East, South and South East Asia, Australasia and the Pacific Islands (AP) region has a number of IoT projects using e-seals, QR codes and X-ray scanners.

In Hong Kong, China, the Single E-lock Scheme (SELS) connects the Intermodal Transhipment Facilitation Scheme of the Hong Kong Customs and Excise Department with the Speedy Customs Clearance of the mainland Customs authority towards establishing a green lane to facilitate the flow of goods through a seamless clearance service. One single e-lock and GPS technology accredited by the two Customs authorities is applied in the SELS under the principle of one single e-lock with separate monitoring.

In Indonesia, the Customs Office of Tanjung Priok seals containers with electronic seals (e-seals) to supervise the transfer of containers and to monitor, in a control room, the shipment history in real time with GPS.

In Malaysia, SmartCargo uses new cargo scanners, integrated with a radiation portal monitor and AI and optical character recognition technology, all linked to the Customs system. The licence plate and container number are run against stored Customs declarations. The image analyst reviews the declaration together with the scanned cargo image while the container is monitored for radiation. Malaysia also has an IoT project for the authentication of a new tax stamp. When the QR code is scanned, the authenticity of the tax stamp is verified, which will lower the risk of counterfeited tax stamps.

Singapore also uses e-seals to enhance the visibility and security of container movements beyond the checkpoints, and has an integrated command centre system to analyse X-ray images from multiple scanning stations.

In Timor-Leste, barcodes are built into the ASYCUDAWorld Single Administrative Document, among others, and are commonly used for the manifest, goods declaration, payments and container pass, and the release and exit of goods from controlled Customs areas.

A number of IoT projects in the North of Africa, Near and Middle East (MENA) region use X-ray scanners and tracking solutions.

Jordan is introducing electronic gates at airports. At the Queen Alia International Airport, in Amman, the government has introduced an automated immigration clearance system to reduce the time it takes for a passenger to pass through immigration to just a matter of seconds. The system uses two-factor authentication of e-gate ID cards utilizing RFID (radio frequency identification) technology and biometric fingerprint verification of passengers.

The United Arab Emirates has a number of IoT initiatives, such as X-raying cargo on the move and a container risk-tracking platform which monitors risks inside containers with scanners integrated into the Customs risk and declaration management system.

The Dubai Customs integrated vessel tracking system uses marine traffic data to track vessels across the world and feeds the data into the internal risk and declaration management system. The marine traffic system uses IoT to collect data transmitted via an automatic identification system of receiving stations that form a marine traffic network.

The South America, North America, Central America and the Caribbean (AMS) region uses IoT for goods inspection and tracking along the supply chain through X-ray and CT scanners, e-seals and licence plate readers.

In Argentina, the Customs Transit Security Initiative (ISTA) uses e-seals for goods in transit, which allows the General Directorate of Customs (DGA) and the Customs transport agent to respond immediately when accidents occur, providing security to the global logistics chain and a reduction in operating costs.

In Chile, seaports have adopted licence plate readers integrated with Customs authorities and port systems.

In Guatemala, the Pedro de Alvarado Customs authority has installed RFID antennas to collect information on goods. More RFID antennas are to be introduced, which will ensure the traceability of the goods and means of transport.

In the United States, CBP is exploring the use of IoT to manage its extensive network of sensors. The objective is to improve domain awareness and to make the data available to a wider audience within CBP by using an IoT gateway.

# 3. Big data, data analytics, artificial intelligence (AI) and machine learning (ML)

## A. What is big data and data analytics and how can they be used in Customs and border management?

Data analytics is the application of computer systems to analyse large data sets to support decision making. It is an interdisciplinary field that incorporates aspects from other scientific disciplines such as statistics, machine learning, pattern recognition, systems theory, operations research, and artificial intelligence. Although its interdisciplinary nature and flexibility of application offer numerous opportunities for use in Customs, at present it is used primarily for risk management. Currently, methods such as fraudulent trade detection and HS code recommendation are chiefly focused on revenue assurance through risk analysis. Adopting a more holistic approach that incorporates data analytics into all aspects should be seen as the next necessary step towards data-driven Customs and border management.

Expanding the use of data analytics to trade facilitation would ensure that Customs procedures become more user-friendly, by observing patterns, and are streamlined to remove difficulties for Customs officials. Beyond trade facilitation, data analytics can be applied to basically any process in Customs and border management, with the only challenge being finding the right way to use data analytics to extract intrinsic value from the analysis.

In order to achieve concrete results from data analysis, Customs authorities must be able to incorporate it correctly into their current procedures. Changes are usually met with resistance, as they are resource-intensive, and their impact is sometimes delayed. Therefore, it is important that agencies are aware of the challenges and how they can create solutions to ease the transition. Assessing current data analytics capabilities, developing an appropriate data strategy, and managing change efficiently are some of the challenges involved. Only when these organizational factors align with the effort to incorporate data analytics can valuable results be achieved.

*In order to achieve concrete results from data analysis, Customs authorities must be able to incorporate it correctly into their current procedures.*

## B. What is artificial intelligence?

Artificial intelligence (AI) is an area of computer science that focuses on the creation of intelligent machines that work and react more like humans. AI refers to systems that change behaviours without being explicitly programmed, based upon data that is observed, collected and analysed. It is a broad term that includes different technologies such as machine learning, deep learning, computer vision and natural language processing that, taken individually or in combination, add intelligence to applications.

AI is the next big technological development where information systems are patterned on biological systems, giving computers human-like abilities of hearing, seeing, reasoning and learning. AI is a computerized system that exhibits behaviour that is commonly thought of as requiring intelligence; systems that think like humans (i.e., cognitive architectures), systems that act like humans (i.e., automated reasoning, learning), systems that think rationally (i.e., inferencing, optimizing) and systems that act rationally (i.e., intelligent software agents).

*The accessibility of cloud computing and the large-scale availability of processing power, combined with the exponential increase in data, has brought AI into focus more than ever before.*

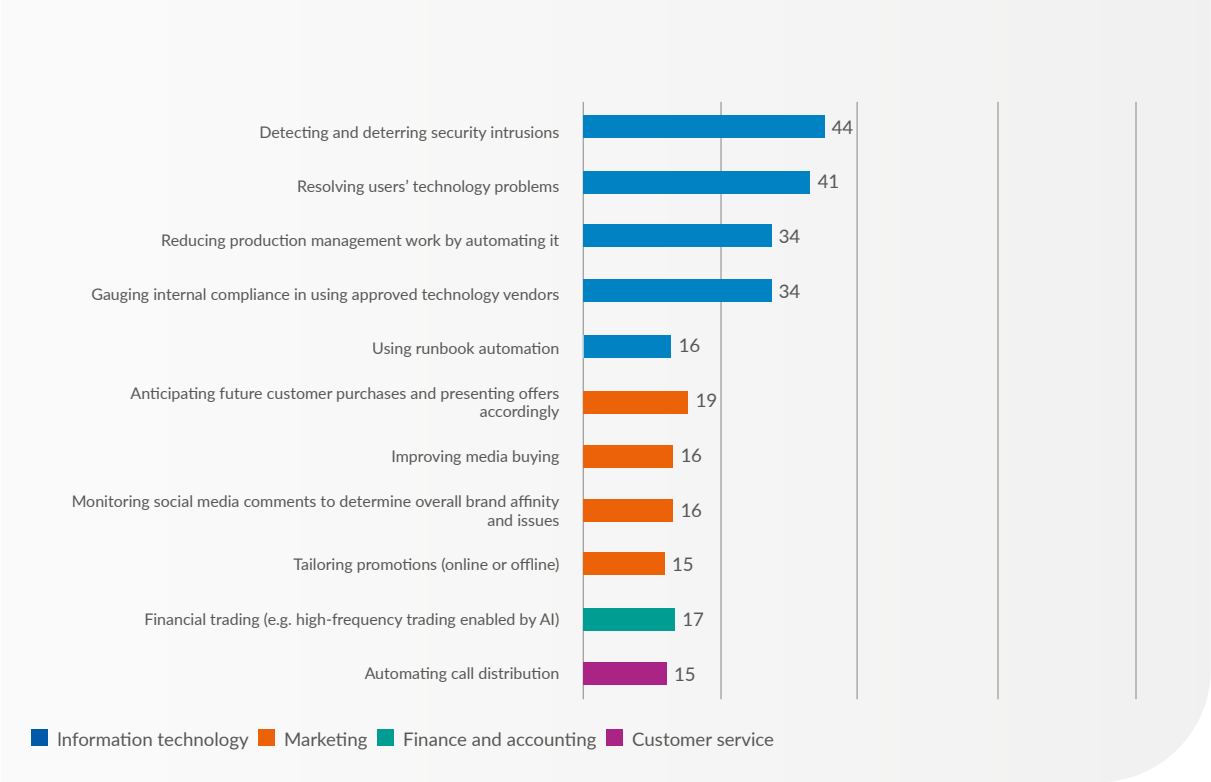
AI is not new; however, it has only more recently received prominence and attention due to a combination of technological developments and events. The accessibility of cloud computing and the large-scale availability of processing power, combined with the exponential increase in data, has brought AI into focus more than ever before.

IoT is one of the newer sources of data that has helped fuel the tremendous growth of AI. IoT is an enabling technology. By connecting sensors and devices to the Internet and managing this centrally through the cloud, there is scope for new opportunities that provide greater insight, allowing for quicker decision-making and response times.

As computer power continues to grow, algorithms and AI models have become more sophisticated and many different use capabilities have evolved. The terms "AI" and "ML" are frequently used interchangeably; however, they are not the same thing. ML can be regarded as a type or sub-set of AI or rather the "application" of AI where machines access data and learn for themselves.

AI is currently being used in a variety of ways around the world. Voice-directed personal assistants and chatbots such as Siri, Alexa and Xiaoice have transformed how people communicate with machines and with technology. Utility companies use AI to forecast electricity demands which allows greater accuracy in planning for high and low periods of demand. Behavioural algorithms are used in thermostats allowing for room temperatures to be adjusted automatically based upon who is in the room. Robots powered by AI run warehouses and automatically replenish stock. AI is being used in weather forecasting, in areas of livestock management and in food safety. The automotive sector has invested heavily in the use of AI in semi-autonomous and autonomous vehicles. The healthcare sector is using AI in medical diagnosis and in-patient data processing. Supply chain and logistics usage is seen in supply and demand forecasting, in manufacturing and in transportation.

*Figure 16: How companies around the world are using artificial intelligence*




*Source: Tata consultancy services survey of 835 companies, 2017*[21]

## C. How can big data, data analytics, artificial intelligence and machine learning be used in Customs and border management?

Use of big data, data analytics, AI and ML in Customs and border management presents a tremendous opportunity in the cross-border movement of people and on the commercial side. As huge volumes of data are generated by people and goods moving across borders, this group of technologies provides the ability to make sense of this vast and ever-increasing amount of data. These technologies can be used to ingest this data and detect and predict patterns more accurately than humans can. Visual search and facial recognition technology, and behavioural and predictive analytics, which are already being used in other sectors, can also be further tailored for use in Customs and border management.

AI can be used for the following purposes:

- revenue collection models, ensuring that the appropriate duties and taxes are collected at the border;
- classification of products under the Harmonized System (HS), simplifying matters for users and enabling greater compliance and certainty for both Customs and the private sector;
- as part of Customs audits to identify anomalies much more quickly and thereby enable Customs auditors to focus on areas of non-compliance;
- to improve risk-based targeting of commercial shipments, as well as to provide and analyse data during shipment inspections using augmented/mixed-reality glasses in detecting contraband and counterfeit goods;
- analysing container images made by X-ray scanners to improve the efficiency of cargo inspection;
- logistics monitoring and control in Customs warehouses and bonded areas;

21 *https://chatbotsmagazine.com/artificial-intelligence-ai-global-trends-how-the-businesses-can-benefit-ai- today-use-cases-9693c542099e, accessed on 13 January 2019*

- identifying high-risk passengers and vehicles by using visual search and facial recognition technology at the border. This can be further expanded to create intelligent analytics to predict future outcomes, facilitating better risk management and preparedness;
- providing better service by placing enquiry robots for passengers at the border;
- providing Customs duty self-payment services by developing mobile apps at the border, etc.

The WCO has developed a number of tools to support Members in developing their data analysis and data analytics skills. The "Handbook on Data Analysis" (2018) is aimed at presenting a high-level overview of data analytics and, more specifically, what it is, how it works, and how useful it may be to Customs and other governmental agencies. The Handbook offers guidance on how to leverage big data and data analytics, outlines data governance-related issues, and presents some common data analysis tools, such as predictive analytics, cognitive computing and statistical programming languages.

The "WCO Capacity Building Framework for Data Analytics" is designed to help Customs officers develop their organizational and technical capabilities to capitalize on the rapid growth of collected data and gain insights to make better-informed, data-driven decisions. Taking into account a WCO survey on data analytics in Customs, information is provided on how to effectively implement successful analytics initiatives and build the organizational capacity needed to make the most of data analytics. The first step, assessment, and planning prior to implementing an analytics project, is addressed by providing a maturity model to measure the current state of data analytics integration. It discusses what data analytics processes should be in place and why appropriate data management is critical. It also presents the appropriate choice of organizational structure, the type of personnel needed, and the critical behaviours and actions that executives should exhibit. Change management is pointed out as a vital tool in a holistic transformation of an organization towards data-driven decision making.

*The WCO has developed a number of tools to support Members in developing their data analysis and data analytics skills.*

In the WCO regional workshops on disruptive technologies held during the course of 2021 and 2022, some Members shared their experience on the use AI/ML in Customs. For example, Botswana Customs implement online payment through a mobile app (BURS Mtax) which provides a number of benefits to the trading Community as well as the revenue authority. The Zambia Customs "TaxOnApp" is another example of this type of implementation.

The Nigeria Integrated Customs Information System (NICIS) Smart Fraud Detection is an AI/ML technology designed to assist Nigeria Customs Service Officers in performing risk analysis on the declaration's information, processing a huge amount of data in the shortest possible time.

Azerbaijan Customs are working on a project on declaration processing using AI/ML.

El Salvador Customs has created an "Artificial Intelligence Department" that works on improving a number of processes by implementing AI, such as risk management, image processing and valuation of goods.

Indonesia Customs uses AI/ML for passenger risk management and import risk management purposes. Russian Federation Customs also uses AI for risk management purposes. Japan Customs utilizes AI for risk management and post-clearance audit purposes.

IoT devices can further enhance existing technologies already in place at border crossings by supplying additional data that can be used by AI for rapid decision-making purposes by the Customs officer. The time series data gathered can be analysed to see what patterns and trends emerge, providing greater insight. The advantage of Customs is that it already has a large amount of data at hand that can be further processed to accelerate smart decision-making at the border.

The vision of Globally Networked Customs (GNC) can be realized through leveraging technologies such as blockchain and by applying AI in the end-to-end intelligent monitoring of the entire supply chain. AI can manage the process of who has ac-

cess to what data and when, ensuring that the appropriate levels of control are in place.

## D. Benefits and Risks

AI provides the potential to significantly increase economic growth and generate major opportunities for countries. Significant benefits can be gained through the use of AI, creating new jobs, extending people's abilities to perform tasks more accurately and efficiently, providing better services, and enabling even faster innovation to occur, together with putting customers in control to protect their data. Along with benefits come certain risks though, if not managed properly. There is a need for strong ethical principles combined with robust compliance and legal frameworks within which AI operates to ensure that AI is not misused. There is also a need for clear and authoritative guidance on how AI can be used, especially in the context of communication using chatbots. As the use of AI increases, labour market reforms will be needed together with job skills training to meet the new human resource needs as the nature of work changes. In the use of AI there is the need for a shared responsibility between the public and private sectors. AI must be transparent so that there is an awareness of how the technology works and what the rules around its use are.

AI risks also include the use of AI for malicious purposes, and could also create uncertainty and distrust in the accuracy of data. Data security can be easily threatened by malefactors using AI technology. Fake content can be more readily created using AI and introduced into business streams. Exploitation of AI systems could occur, thereby skewing the results. The integrity of the underlying data and information will be paramount.

Additionally, provisions governing the application of AI-based information and determinations, such as HS classification tools, are needed to ensure effective compliance. Access to robust and transparent redress mechanisms will be required to ensure the integrity and ongoing improvement of AI processes.

*AI provides the potential to significantly increase economic growth and generate major opportunities for countries. Along with benefits come certain risks though, if not managed properly.*

## E. Potential Future Use

AI can greatly assist almost every function in government. Implementation of chatbots in government agencies can greatly enhance communication between the government, companies and citizens. Chatbots are interactive applications that are powered by AI and interact with users through natural language. A chatbot could serve as a channel for access to Customs in situations where certain services could be delivered more efficiently and cost effectively. Chatbots can rapidly capture and manage large volumes of user requests and sort through information and databases to deliver results to the user. Routine communication can be automated, questions answered and recommendations made, which would free up officers to focus on higher-value work. The types of government services provided could be transformed and government operations optimized. Predictive analytics for the management of services and assets could be used to forecast demand and measure levels of usage. More effective compliance could be attained in reporting and in collection of taxes and duties.

A number of Customs administrations already use chatbots to respond to the questions they receive on the website. For example, Zambia Revenue Authority uses an AI chatbot "Zax" to engage with taxpayers, alongside other customer service channels including phone, email, and social media etc.

Use of AI with augmented or mixed reality glasses could be employed by Customs for training purposes as well as for shipment inspections and in the detection of counterfeit and contraband goods. Data would be available in real time, enabling officers to make quicker determinations, thereby increasing the number of inspections, accuracy and volume of goods that could be reviewed.

*A number of Customs administrations already use chatbots to respond to the questions they receive on the website.*

*Box 4 : Frequently Asked Questions*

### 1. What is AI?

- AI is a computerized system that exhibits behaviour that is commonly thought of as requiring intelligence
  - systems that think like humans (i.e. cognitive architectures)
  - systems that act like humans (i.e. automated reasoning, learning)
  - systems that think rationally (i.e. inferencing, optimizing)
  - systems that act rationally (i.e. intelligent software agents).
- AI is not just one type of technology but rather a broader term covering multiple technologies which include machine learning, deep learning, computer vision, natural language processing and other technologies, used individually or in combination, to add intelligence to applications.

### 2. What is ML?

- ML is a subset of AI that provides computers with the ability to learn without being explicitly programmed.
- it is the process of using mathematical models to predict outcomes versus relying on a set of instructions. This is made possible by identifying patterns within data, building an analytical model, and using it to make predictions and decisions. Machine learning bears similarity to how humans learn, in that increased experience can increase accuracy.

### 3. What is Deep Learning?

- Deep learning is a subset of machine learning algorithms that learns by using a large, many-layered collection of connected processes and exposes them to large sets of examples. This layered structure of algorithms is called artificial neural networks and is inspired by biological neural networks that the human brain uses. Deep Learning helps enable computers to hear, see, speak and even understand natural language commands.
- Deep learning is a method of information processing and a subset of machine learning. The key difference lies in whether humans intervene in the learning process: in machine learning, humans intervene in the analysis of the data and the actual decision-making process. In contrast, deep learning models are able to learn on their own. This happens in that the systems repeatedly link what they have learned with new content. As a result, they expand their learning. In this learning process, the human does not intervene, the analysis is left to the machine.

### 4. Is AI a new field of technology?

- No. The technology has been developed over several decades. However, due to the greater accessibility of cloud computing, increasing computer processing power and an exponential increase in data, AI usage and development has received greater visibility and use.
- The progress made in recent years is largely based on three developments: the increased availability and amount of data, the growing power of cloud computing, and powerful AI algorithms. Algorithms are systematic instructions for solving a mathematical problem.

### 5. What can AI do?

- AI can take in more data and detect and predict patterns more accurately than humans can. Use of AI can lower costs and mitigate risks.
- AI will affect almost all areas of our lives and has the potential to make great economic and social progress. It can also help us meet the pressing challenges of our time, in the areas of climate and species protection, for instance. AI supports researchers at the Snow Leopard Trust, for example, in protecting endangered snow leopards.
- AI technologies such as machine learning make it possible to analyse and interpret data volumes, recognize patterns from them and create decision-making bases – much faster than humans can. Patient data can be analysed with the help of AI, for example, and the information obtained can allow drugs and therapies to be tailored to individual patients.

*Continuation box 4: Frequently Asked Questions*

### 6. Will jobs be lost due to AI?

- Some jobs will be lost while new ones will be created. Workers will need to gain skills that are relevant in the changing workplace as new skillsets will be required for new markets.

### 7. What risks does AI pose?

- Workforce inequality could arise through increased automation and use of AI making certain jobs redundant. Privacy and ethical concerns could also arise as a result of the misuse of AI. Bad data could intentionally be introduced into the system.
- The role that AI will have in our lives shows that AI-based systems must be reliable and secure, and they must be able to operate continuously. Not only under normal conditions, but also in unexpected circumstances – and even when they are attacked. The security of artificial intelligence is crucial to its acceptance.
- AI offers enormous potential to improve people's lives. But we will only be able to seize that potential if we ensure data protection in conjunction with the use of artificial intelligence. No one will share their personal data if they cannot be sure that their data is safe. And without this data, AI cannot make informed decisions. To gain consumer confidence, control mechanisms are needed that allow people to decide for themselves how their data is to be used. AI systems may only use personal data in accordance with applicable data protection standards, and must respect privacy.

### 8. How can Customs implement AI?

- AI can be implemented in different areas and at different stages based on Customs' needs. This may be through software, or through combinations of software and hardware. Specific case studies would need to be created based upon priorities and returns on investment. The initial implementation is usually in areas of IT and in data analytics.

### 9. What are the prerequisites for AI implementation?

- To implement or integrate AI, intelligent software applications and tools need to be built for Customs use. Software developers and data scientists need to understand Custom's objectives and design applications to suit their needs. Pre-built software services such as vision, speech, language, knowledge and search functions can be leveraged and tailored for specific use or custom software applications, and algorithms can be built for specialized use.
- We can consider seven steps to implementing AI:
  - define a clear use case
  - confirm data availability
  - undertake basic data exploration
  - specify a model-building methodology
  - define a model-validating methodology
  - automation and production roll out
  - update the model periodically.

### 10. Is AI a stand-alone application/technology?

- AI is not one technology or stand-alone application but rather an umbrella term that includes multiple technologies and applications.

### 11. What other technologies does AI support and how?

- AI is a broad term and covers a number of different technologies. AI can be integrated with legacy systems as well as with newer cloud applications. AI algorithms can be tailored to meet different Customs needs and types of software applications to perform assignments ranging from basic tasks up to advanced decision-making. AI can drive advanced analytics and operate virtual assistants or chatbots, from computer systems to advanced robotics.
- With the growing data landscape, two of the most common capabilities required to manage as well as extract value out of Customs and trade data are data cataloguing and data warehousing. AI will simplify the ability to

*Continuation box 4: Frequently Asked Questions*

integrate these two capabilities, giving Customs authorities the freedom to query data on their terms, using either serverless or dedicated options - at scale.

- Data mesh is a democratized approach to managing data from various clouds where various domains operationalize their own data, encompassing data, technology, processes, and organization. Rather than looking at data as one huge repository, data mesh considers the decomposition of independent data products.
- Confidential computing allows Customs authorities to isolate sensitive data while it is being processed, and to secure financial data, protect traders information, run machine learning processes on sensitive information, or perform algorithms on encrypted data sets from multiple sources.

### 12. In which areas of Customs management can AI be introduced?

- AI can be used in almost every area in which data and decision-making is involved. It can analyse huge volumes of data faster than humans can, enabling faster and more accurate decisions to be taken. It can be introduced in automated kiosks at borders where virtual assistants or chatbots aid in screening passengers. AI can provide information or self-help tools to traders in a 24/7 environment.
- Cognitive Services for Customs agencies help improve compliance and facilitation by enabling Customs officers to make better decisions. Data analytics – for example, automated selectivity rules – has become an increasingly important tool for Customs agencies. ML capabilities help solve general problems such as analysing text for emotional sentiment, analysing images to recognize objects or faces, converting speech (audio) to text, translating the text into many languages, then using the translated languages to get answers from a knowledge base.

### 13. What kind of changes will AI bring to Customs in the future?

- AI will place more information and data intelligence at the disposal of Customs, which will enable faster decision-making in areas of risk management in the cross-border movement of both people and goods. Through increased automation, certain repetitive tasks can be automated through AI allowing Customs officers to focus on more value-added activities.
- The end-goal of applying various AI components is to enhance Customs operations. Visual search and facial recognition technology, behavioural and predictive analytics, revenue collection models, classification of products, Customs audits, risk-based targeting, analysing container images from X-ray scanners, logistics monitoring, identifying high-risk passengers and vehicles etc. can all be tailored for use in Customs and border management.

### 14. What can Customs do to mitigate the risks raised by AI?

- Customs can act as "guardians" in a sense, creating and defining the proper regulatory frameworks to control how AI is used for Customs purposes and how the data is gathered and shared with other regulatory agencies, countries, businesses and citizens it interacts with. Customs can develop robust and transparent redress mechanisms to ensure the integrity and ongoing improvement of AI processes. Customs can also work with the private sector to establish the framework around privacy, and the pace and adoption of digital tools.
- Adhering to responsible AI principles and standards is critical to addressing the societal impacts of AI and building trust as the technology becomes more and more a part of the products and services that people use at work and at home every day. AI systems should be fair, reliable and safe, private and secure, inclusive, transparent, and accountable.

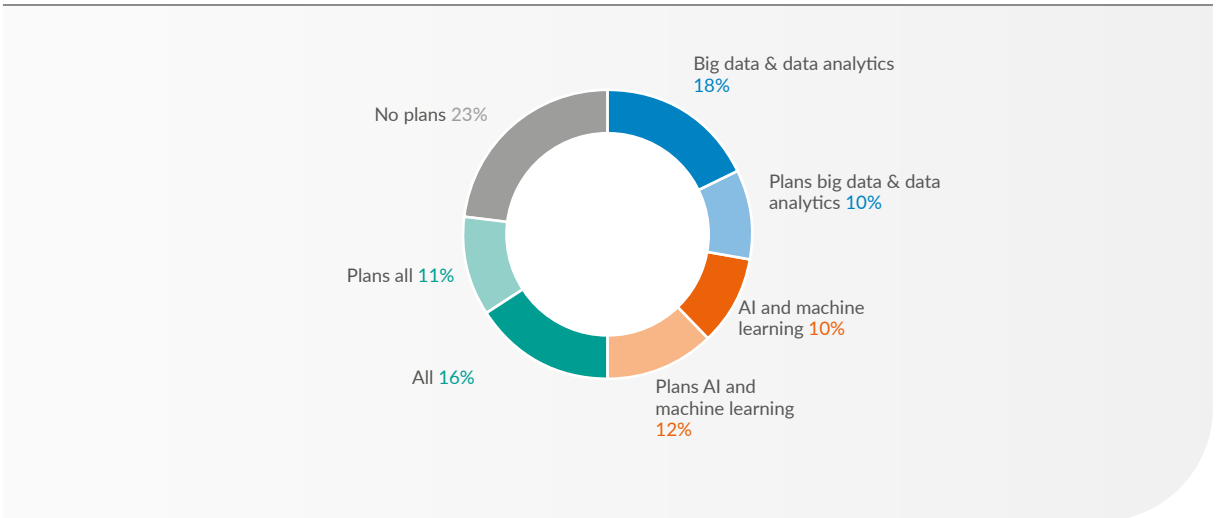
## F. Implementation by Customs in 2021

According to the results of the WCO Annual Consolidated Survey 2021 and the WCO-WTO paper "The Role of Advanced Technologies in Cross-border Trade: A Customs Perspective", almost 45% of Customs authorities use either data analytics, or AI/ML, or both. Big data analytics is currently used by 18% of the responding Members, while 10% are planning to introduce it. Another 10% use AI/ML, while 12% are planning to introduce it. In addition, 16% use both data analytics and AI/ML, and another 11% are planning to introduce both. This means a total 44% of Customs authorities are currently using either data analytics, or AI/ML, or both, while another 33% have plans to do so. 23% of respondents currently have no plans to implement these technologies.

### Benefits and challenges

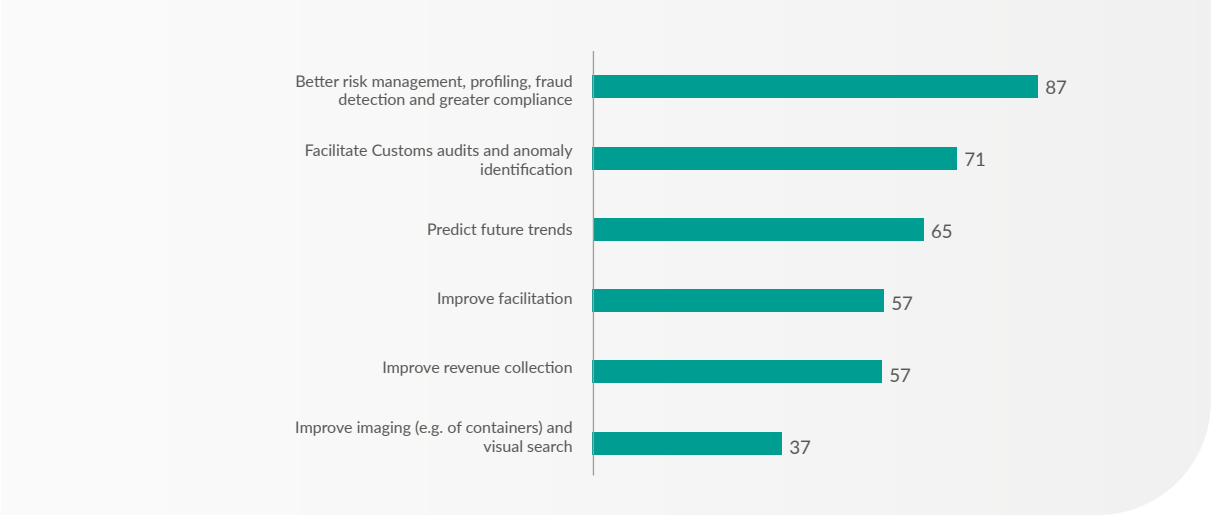
The majority of Customs authorities see clear benefits from this group of technologies, with risk management and profiling, fraud detection, and greater compliance being the most prevalent. Facilitating Customs audits and identification of anomalies, and improving revenue collection, were also emphasized by a number of Members. Predicting future trends, enhancing trade facilitation, and improving imaging and visual search technology were also indicated as benefits.

*Figure 17: Stage of adoption of big data, data analytics, artificial intelligence and machine learning*




*Note: Total respondents numbered 94.*

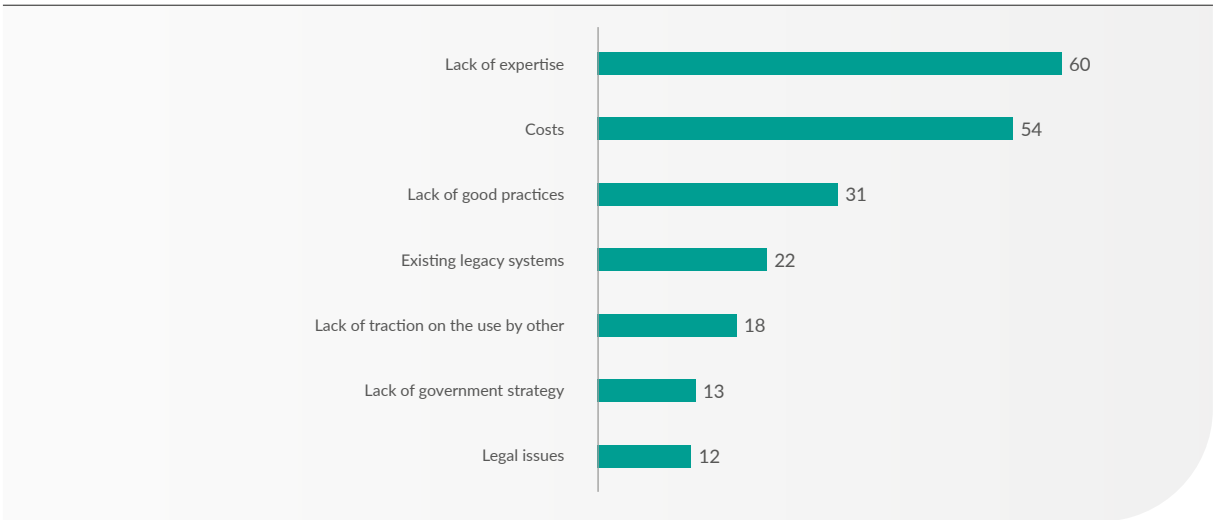
*Figure 18: Main benefits of introducing big data, data analytics, artificial intelligence and machine learning*




*Note: Total respondents numbered 94.*

However, lack of expertise is the biggest challenge for Customs authorities in implementing big data analytics and/or AI/ML technology. Other challenges include costs, lack of good practices, existing legacy systems, lack of traction in the use of the technology by other stakeholders, lack of a government strategy, as well as legal issues. Members also highlight other challenges such as data governance issues, data quality, information organization, roles and functions, and existing tool problems.

*Figure 19: Main obstacles to adopting big data, data analytics, artificial intelligence and machine learning*




*Note: Total respondents numbered 94.*

Data analytics and AI/ML were considered to have potentially the biggest impact on Customs operations in the future. The survey results show a high level of confidence by Members in a technology that has already been used for some time and the use of which is constantly increasing, in particular for improving the risk management capabilities of Customs.

## Areas of implementation

Many Customs authorities have provided information on their respective implementation projects and the case studies for data analytics and AI/ML in different areas.

**1. Risk management:**
- data mining for intelligence purposes and risk management,
- AI/ML for enhanced risk management processes (inspection results feedback loop, client segmentation, automatic assessment, and upgrade of risk profiling),
- compliance risk scoring in commercial and trade activities,
- identifying low-value courier and postal shipments to improve risk assessment,
- identifying low-risk individuals at borders, and
- automated targeting system.

**2. Tariff classification:**
- HS classification using AI,
- tariff misclassification and non-compliance with tariff advice.

**3. Scanning:**
- developing AI-based models for interpreting X-ray images,
- ICT scanners with AI to enhance enforcement capabilities and Customs clearance efficiency.

**4. Revenue collection:**
- potential anomalies in high-revenue areas, including excise equivalent goods (alcohol, tobacco, and petroleum),
- automate repetitive manual procedures involving revenue protection; one of the procedures involves online research of market prices and deploying AI to assist in conducting intelligent filtering of research results,
- price recommendation data analytics,
- undervaluation and overvaluation anomaly detection,
- enhancing efficiency in using financial and tax data more widely and strategically in order to improve compliance and performance in terms of public revenue collection and the fight against smuggling.

**5. Others**
- post-clearance audits and controls,
- chatbot for answering online public enquiries,
- chatbot for a physical robot to answer enquiries from travellers at control points,
- misuse of concessions, including: tariff concession orders, by-laws, free trade agreements, origin masking,
- dumping and countervailing anomalous activities,
- refund/drawback non-compliance,

- imports of prohibited goods,
- cross-platform cyber patrol,
- analysing massive volumes of Internet information to identify IPR crime trends,
- implementation of data mining on import,
- trade circumvention graph analytics,
- export/import data analytics,
- a data lake developed for the consolidation and single source of truth of all Customs data; monitoring the service delivery performance in real time, as well as providing historical insights into Customs statistical information for future planning and forecasting,
- develop advance analytics for AEOs.

### Ongoing projects

A number of projects have been implemented by Customs authorities in different regions and some of them are elaborated in detail as case studies in the Annex to this Study Report.

For example, the U.S. CBP established the AI Center of Innovation (COI) in late 2020 to act as the catalyst to create the enterprise processes, tools, and infrastructure needed to rapidly develop, test and deploy new AI solutions.

Hong Kong Customs launched a pilot IT system, the Cargo Big Data System (CBDS), in November 2020, aiming to apply big data analytics and artificial intelligence (AI) to cargo clearance to analyse the ever-changing trade pattern and trend in order to effectively combat cross-border smuggling crimes.

Alongside typical risk indicators (such as the code of the goods and its weight description and destination, etc.), Russian Federation Customs use complex risk indicators based on the analysis of big data and the use of AI.

In 2017, Japan Customs started a study on X-ray image analysis with AI. Then in 2019, they started to develop the AI models using big data, including Customs declaration data.

Belgium is implementing the 'Behavioural consequences of tariff changes' (BCTC) project to analyse the impact EU Customs tariff measures have on commodity trade flows. The central goal is to detect fraudulent behaviour by economic operators following the introduction or increase of tariff measures. More specifically, the project aims to detect sudden behavioural changes in an operator's import profile deviating drastically from the "normal" trends observed before the tariff measure was imposed.

Zambia Revenue Authority (ZRA) uses an AI chatbot "Zax" to engage with taxpayers alongside other customer service channels including phone, email, and social media etc. The taxpayer service chatbot uses natural language processing to answer basic questions via a business messenger. These may be questions like "What are Customs duty rates?" or "What are the due dates?", etc.

*The majority of Customs authorities see clear benefits from this group of technologies, with risk management and profiling, fraud detection, and greater compliance being the most prevalent.*

# 4. Biometrics

## A. What are biometrics?

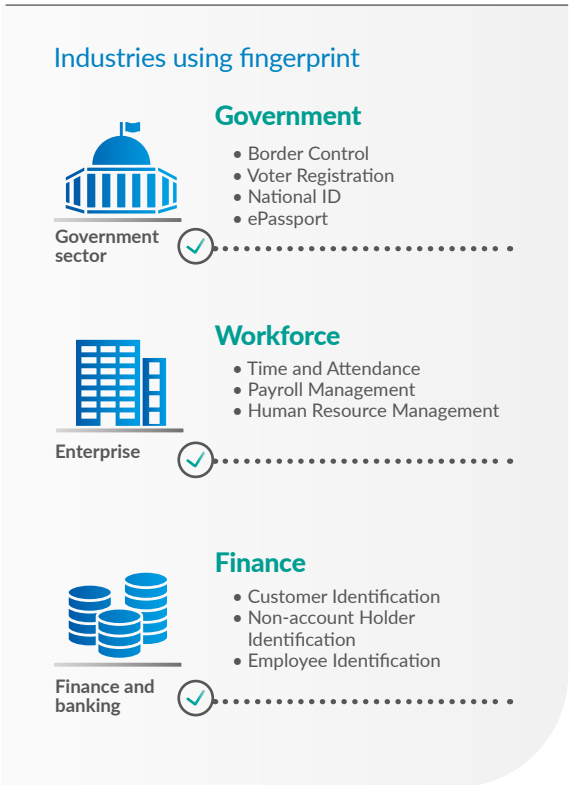
Biometrics is the measurement and statistical analysis of an individual's physical and behavioural characteristics. The basic premise of this field is that every individual person is demonstrably unique and therefore identifiable via his or her physical or behavioural traits.

To understand biometrics, we first need to distinguish between biographic data and biometric data. Typically, governments and other actors seeking to verify identity use biographic data. For example, an individual's date of birth is biographic; this information is specific and permanent about an individual, but is not readily observable from the individuals themselves without them self-reporting it, or it being recorded and reported from another source. Thus, there must be an act to link the recording of the individual's date of birth with the individual. Biographic data includes text data commonly found on the data page of a traveller's passport, such as name, date of birth, and country of citizenship. Biographic data is not unique to the individual. For example, many people share the same date of birth. As biographic data must be transmitted in text, it is also susceptible to error and easy to misuse.

A biometric system, on the other hand, features the use and recording of a physical component of an individual that is unique to that specific individual and does not need to be translated into a textual record; i.e. the information can be collected and identified in its original source (the individual), and does not need to be transitioned to another medium (i.e. text). In the past, due to nascent technology, the only biometric information available to law enforcement and other actors seeking to verify identity was fingerprints. For many years, even this was an inexact science, based more on assessment by trained professionals than on automated identification via computer. This biometric identifier was also subject to human error, poor recording/capturing of fingerprints, and technological limitations in reproducing the recorded print. However, technology increasingly allows governments and other actors to identify and confirm fingerprints automatically via computer. Technology has also produced significant developments in facial recognition technology, DNA, and iris imaging, allowing new sources of information to verify an individual's identity. Besides the above sources of biometric data, other examples can include palm veins, palm prints, hand geometry, and odour/scent. Behavioural characteristics can also serve to biometrically identify an individual. Such behavioural identifiers include typing rhythm, gait, and voice recognition.

Governments and organizations all around the world are choosing biometric technology to combat identity fraud and security breaches, secure confidential data, reduce costs and improve overall user experience. Biometrics is one of the rapidly growing fields in the information technology sector, with fingerprint recognition expected to remain the most dominant form of biometric technology.

*Figure 20: Industries using fingerprint*




*Source: Bayometric*[22]

There are a number of examples of how government and private actors are utilizing biometrics to identify individuals. For example, Disney theme parks are now using the biometric measurements (fingerprints) of theme park guests to ensure that tickets issued are being used by the same person over multiple days of attendance. A much larger example is Aadhaar, India's national identity programme, now the largest biometric database in the world. Aadhaar is a 12-digit unique identity number issued to all Indian residents based on their biometric and biographic data. Aadhaar is designed to enable Indian government agencies to deliver public services securely, based on both the biometric data (including fingerprints, iris scans, and facial photographs) and biographic data (name, age, gender, address, parent/spouse name, mobile phone number, email ID) of an individual. The data is transmitted in encrypted form over the Internet for authentication. As of 15 February 2018, Aadhaar had 1.17 billion enrolled members out of India's population of 1.31 billion. A total of 99.7% of India's adult population had been enrolled in Aadhaar, as of December 2021.

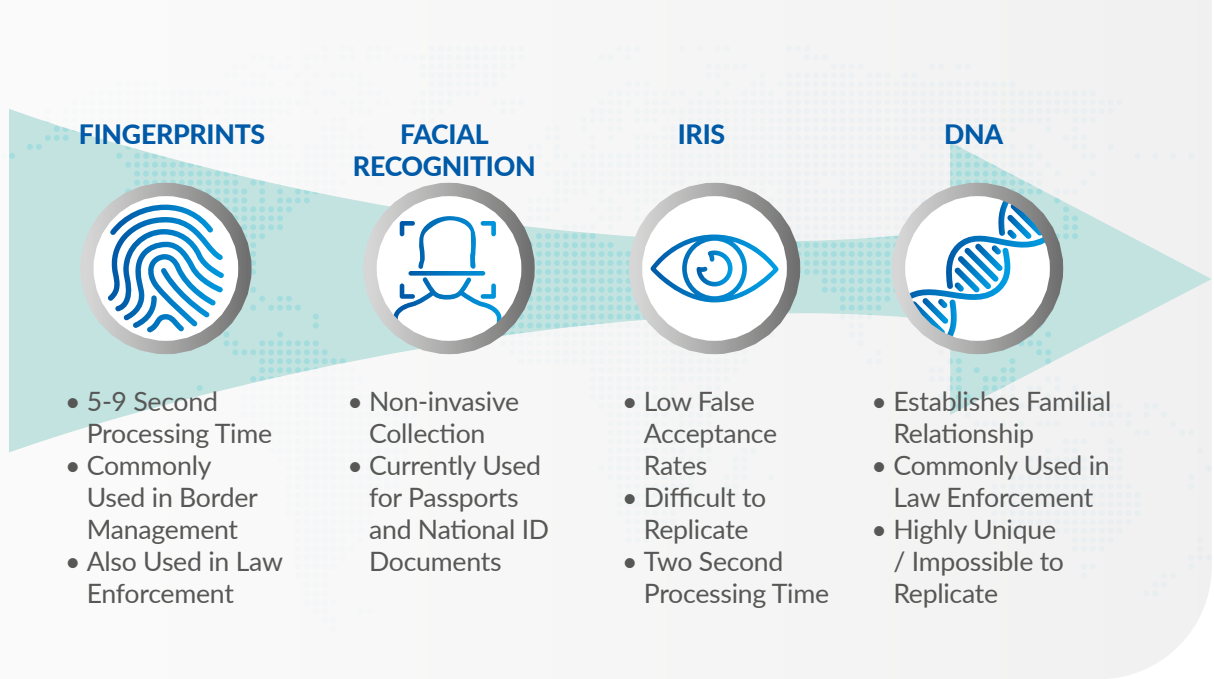
## B. Current use in Customs and border management

Customs professionals may ask why biometrics, which is focused on the identification of individuals, is relevant to the core, traditional mission of Customs, which focuses primarily on the movement of physical goods. It is true that biometrics presents a great opportunity for immigration and border security enforcement; however, looking to the future, Customs agencies will also likely find many opportunities in the development of biometrics.

Customs administrations enforce laws/regulations relating to the movement of goods across borders; this inherently includes investigations of individuals associated with those goods, up to and including inspections, and/or investigations, prosecutions, and civil remedies against those individuals. Access to the biometric data of individuals who are engaged in crimes related to trade (goods) can facilitate Customs' efforts to identify, investigate, apprehend and prosecute these wrongdoers. False identities could be more quickly identified through the unfalsifiable records of biometrics. Biometrics thus can be a force maximizer for all law enforcement entities, including Customs. Individuals identified by Customs agencies using biometric information may also alert those agencies to existing warrants or other information that may require additional action.

22 https://www.bayometric.com/importance-of-biometric-fingerprinting-technology/

*Figure 21: Fingerprints, Facial Recognition, IRIS, DNA*




*Source: arcAspicio*[23]

In addition, Customs administrations are uniquely situated to demonstrate useful methods for interagency coordination, which biometrics requires. Customs administrations also have a long history of coordination and interagency work, in enforcing laws and regulations for partner government agencies. They are often co-located with immigration agencies, and can work to promote the adoption of and facilitation of such efforts. Customs, as a leader in coordinated border management, is uniquely positioned to bring partners together to leverage the biometric data tool. In order to close information gaps, Customs and immigration agencies should seek to partner with one another to improve data collection, enhance existing systems, and implement automated technology, which will support the identification and targeting of persons of interest seeking to depart countries, as well as enhance the capability to identify immigration violators.

Biometrics enhance identity verification in a border management and homeland security context. DNA is an emerging biometric in this area.

Governments and immigration authorities could be expected to eventually use biometrics at airports. Tokyo's Narita International Airport is testing a new biometric process for the journey from check-in to boarding. The process requires passengers to check in at one of Narita's new biometric kiosks, which captures their facial image and matches it against their passport. From there, they can drop off luggage at an automated baggage drop point that verifies their identity by camera. Cameras at security checkpoints and boarding gates also verify passengers' identities, making it unnecessary for passengers to show paper documents.[24]

In the WCO regional workshops on disruptive technologies held during the course of 2021 and 2022, some Members shared their experience on the use of biometrics.

For example, the Australian Border Force (ABF) uses biometric identification services in visa and border processing. Facial and fingerprint biometrics are already collected from a range of visa and citizenship applicants at offshore and onshore locations. This allows the ABF to handle any risks relating to visa applicants offshore. The ABF also uses SmartGates, which perform an automatic face-to-passport check of the traveller at the Border. Prior to the COVID-19 pandemic, approximately 70% of travellers departing Australia and 50% of arriving travellers self-processed using SmartGates. As part of a broader programme

23 https://www.arcaspicio.com/insights/2009/3/19/dna-the-last-biometric.html, *accessed on 13 January 2019*
24 https://www.businesstravelnews.com/Global/Narita-Introduces-Biometric-Airport-Journey-Process

in response to delivering a bio-secure border, the Digital Passenger Declaration (DPD) will be replacing the existing Incoming Passenger Card. All travellers wishing to come to Australia will be required to complete a DPD. This will anchor identity through the collection and use of biometrics.

Azerbaijan Customs are also working on biometrics. A facial recognition pilot was completed in 2020 by Huawei at the southern border crossing point with Iran. The system detects frequent border crossers who have criminal charges against them, and the detection rate is 90%.

## C. Potential future use

Given that biometrics technology is still in its infancy, additional innovations and uses will likely arise as the technology improves and becomes more ubiquitous. Customs agencies, other government partners and private actors should monitor this field closely to identify additional uses. Some potential uses on include the following examples:

*Biometrics enhance identity verification in a border management and homeland security context.*

Biometrics can be used to verify identities and control access by Customs operators. Customs agencies frequently operate in or utilize restricted areas and facilities, including ports of entry, secure areas of airports, land ports, and seaports, storage spaces for weapons, vehicles, uniforms, working animals and equipment, and evidence lockers. Customs agencies also often utilize protected computer and other information systems for the storage of, and access to, protected information. Current methods of protection utilize identity cards, passwords, and other information created by or assigned to the individual user. Biometrics allows the opportunity for the creation of a unique operator signature. An operator signature is a biometric mode where the manner in which a person seeking access to a restricted device/system or controlled area must first submit biometric information (for example, a fingerprint or iris scan) to a verification template. Thus, access would be dependent upon the biometric data that only that user possesses, as opposed to a password or biographic data which can be used by any person, including non-authorized users of that information, so long as they possess it. This would greatly enhance the current defences of protected locations and systems when coupled with the existing use of password/identification processes. This would in turn boost not only the personal security of the Customs officers, but also the security of the information, systems, and locations.

Biometrics could likewise be utilized to prevent crime in the international supply chain. It has a potential use in ensuring the identity of Customs actors, including Customs brokers and other licensed freight-forwarders and logistics operators, ship/aeroplane and other conveyance crews, and other actors in the international supply chain. Technologies utilizing webcams, fingerprint readers and retinal scanners could conceivably be incorporated into workstations, entry points, and other portals of restricted access to ensure security/verify identity. This would provide greater protection and significantly decrease identity theft and other security breaches in the Customs environment. This will become increasingly important as many professions, including Customs brokers and other actors in the international supply chain, shift increasingly online.

Biometrics may also reduce the ability of shadow companies to exploit the international supply chain for illegal gains. For example, registered agents for corporations and other importers/exporters could be required to submit biometric identifiers. Shell corporations could be more easily investigated for alleged criminal/civil wrongdoing if governments move towards requiring biometric data of officers/agents during incorporation. Individuals performing the work of such corporations under investigation for alleged violations would be more easily detectable. Unlike biographic data recorded in fraudulent documents, biometric data is not easily substitutable/switchable.

Biometrics' greater reliability and security can be leveraged to strengthen existing security systems/regimes. For example, biometrics could

become an additional factor of consideration in the assessment of authorized economic operator programmes (AEO) and other supply chain security regimes. Actors in the international supply chain may seek to use biometric data to verify their drivers, crew members, and individuals with licences or other certifications, etc. Biometrics may become commonplace in security systems the world over, and eventually become a part of the consideration of AEO certification and mutual recognition.

## D. Considerations for establishing a biometrics programme

As Customs agencies and other actors in the international supply chain move toward the wider implementation of biometrics, there are several considerations that administrations must take into account. The realities of biometric data gathering/use, specifically individual habits, stakeholder participation and technological considerations, will guide implementation.

- **Performance of biometrics will also require additional technological developments to ensure reliability:** The quality of biometrics recording can vary depending upon many factors, including seemingly benign factors such as (in the context of facial recognition) the presence of natural light, the type of lighting fixtures, and the height of the ceiling in recording locations. Secondly, governments are already discovering performance differences between travellers from different countries. This includes issues with diverging quality of the images in ePassports. In addition, false rejection rates can vary depending on age and gender. While work may remain to perfect this technology, over the past five years there have been significant gains in the accuracy and reliability of facial recognition technology.

- **Legal authorities/barriers:** Customs authorities need to ensure that they have the legal ability and required protections in place to collect, share, and utilize biometric data. There may be barriers to advancing work between bilateral partners, as these legal authorities are identified and potential methods to update legislation, ensure compliance with existing regulations, or mitigate risks are weighed.

- **Non-compatibility of information-sharing systems between agencies:** Information collected by immigration and other law enforcement entities may not be readily connectible to Customs systems, or useable under Customs authorities/legislation. There can be significant technological, legal, and financial obstacles to addressing these barriers.

- **Physical barriers to implementation:** Airports, seaports, land ports of entry, and other facilities where Customs agencies operate may not be built in a way that is conducive to collecting biometric information, i.e. their construction would have been concerned largely with the immigration aspect of travellers, and not with the needs of Customs. Hardware would have to be updated or replaced to ensure the efficient and safe use of this new technology; the greater security offered by biometrics and its perhaps eventual ubiquitousness may justify these significant resource needs.

- **Expectations and business practices of the trade and travelling public:** Airlines, maritime shippers, and other participants in the international supply chain will need to be involved closely in the development/implementation of biometric information collection and analysis by any government actor. Public education and clear on-site guidance will be necessary in order to ensure the participation of, and compliance by, participants in the international supply chain and Customs processes. Any insertion of new information checks such as biometrics will also need to ensure it is implemented in a way that makes sense for existing business processes, and the value-added is greater than the additional burden of installation, maintenance, and related training.

*Biometrics may also reduce the ability of shadow companies to exploit the international supply chain for illegal gains.*

- **Sufficient IT and personnel resources**: Implementing agencies will need to ensure sufficient IT resources, including software, hardware, privacy protections, bandwidth, etc. Administrations will need to be quick to recognize any flaws in processes identified by the current testing, and determine reliable and cost-effective biometric solutions.

- **Political will:** Significant time and resources are required to address these challenges. None of this can be accomplished without the support of leadership. The value of biometrics must be clearly demonstrated to ensure the espousal of this technology by Customs agencies and other users. As biometrics becomes more common, it may actually piggy-back onto this process as ubiquitous technology rather than having to be adopted in a separate process.

## E. Concerns about security and use of biometric data

Many parties have significant concerns about the use of biometrics, in particular that it may not be limited to mere identity verification. Biometrics can be used to keep airports and seaports secure, but can also be used to identify individuals participating in public protests, as well as to remove anonymity of movement in a world already replete with security cameras and access chokepoints. However, many users have already willingly surrendered a significant degree of privacy due to the benefits of convenience, access, and security it has provided (for example: mobile phones and location technology, credit cards, security cameras).

Any new restriction on access to a location or system inherently creates an incentive to falsify information in order to gain access to it; care will need to be taken that the biometric information submitted originally is accurate, and work will have to be put into the ongoing monitoring of the integrity of these systems. All systems must incorporate features to protect information that is susceptible to security breaches/hacking. We must not become overly confident that biometrics will eliminate identity theft and other forms of fraud in Customs enforcement.

- **Cancellable biometrics:** One advantage of a password or other assigned identifier system over biometrics is that password-based identifiers can be re-issued. If a token or a password is compromised, system administrators can cancel and replace this identifier. This ability is not naturally available in biometrics. If the recording of an individual's face, iris, or other biometric data is compromised through technological error or deliberate sabotage, the individual cannot cancel or be reissued a new verifier; instead, the system has to be updated to clarify that the individual's original biometric data is valid.

*Biometrics could likewise be utilized to prevent crime in the international supply chain. It has a potential use in ensuring the identity of Customs actors.*

- **Burdens of hardware:** Whereas access to previous systems and locations could be obtained through biographic or password identifiers, biometric data requires the physical presence and participation of the individual from whom the biometric data has been gathered. This can require the installation of hardware in multiple locations to enable the recording and verification of biometric identifiers for individuals seeking to gain access to systems from remote or disparately located workstations. For example, a Customs broker could be required to submit biometric data to confirm their identity, and have to purchase an iris scanner in order to submit this data from their office. This creates a new burden of procurement, and hardware integrity, for governments and other actors in the international supply chain, and could present an unfair burden on small businesses and individuals over larger companies.

- **New danger to individuals:** When individuals seeking to compromise security cannot access secure systems/locations, the limitations of biometrics increase the chance of physical danger to individuals with the biometric information that can access those systems/locations. If the item is secured with a biometric device, the damage to the owner could be irreversible, and potentially cost much more than the property it secures. In a particularly gruesome example, in 2005 Malaysian car thieves cut off the finger of a Mercedes-Benz S-Class owner when attempting to steal a car which required a fingerprint scan to function. This creates a new threat to Customs officers and actors in the international supply chain.

*Many parties have significant concerns about the use of biometrics, in particular that it may not be limited to mere identity verification.*

- **Merely a stop gap in information/location security:** Creating a new method/system to secure a system or a location inherently creates the incentive to hack or otherwise circumvent that method/system. There are innumerable examples of secured communications and systems belonging to wealthy and powerful government and private entities being compromised by criminal organizations and entities seeking to harm or destabilize these system users (examples: WikiLeaks, Panama Papers), as well as by terrorist organizations and their supporters. It is not unforeseeable that the widespread adoption of identity verification technology utilizing biometric data will in turn beget technology which can bypass these checks (for example, distortion technology to make a face appear to look like another; contacts or other inserts which allow retinas to mimic another person's; or technology to alter or create false records on the otherwise legitimate biometric data collected on individuals). This is the perpetual challenge of law enforcement attempting to stay ahead of the game.

Biometrics can offer innovative opportunities for law enforcement; but it also requires more of the basics that Customs agencies are always seeking to achieve, i.e. coordination, information sharing, and mutual support and trust. International forums like the WCO will be important venues for sharing success stories and cautionary tales on

biometrics, and for establishing the required international standards, fostering cooperation and mutual assistance, and information sharing.

## F. Ongoing projects in Customs

A number of projects are being implemented by Customs authorities in different regions and some of them are elaborated in detail as case studies in the Annex to this Study Report.

For example, the U.S. CBP uses biometrics including fingerprints and facial comparison technology for passengers. Another example is Japan Customs, which in April 2019 introduced electronic Customs declaration gates (e-gates) to facilitate smooth entry, shorten the waiting time and reduce congestion at the Customs inspection area. Passengers can now go through the gate smoothly and speedily using an electronic declaration on their smart-phones and the facial recognition system, as long as there is no need for a declaration and they are not subject to inspection.

*Biometrics can offer innovative opportunities for law enforcement; but it also requires more of the basics that Customs agencies are always seeking to achieve, i.e. coordination, information sharing, and mutual support and trust.*

# 5. Drones

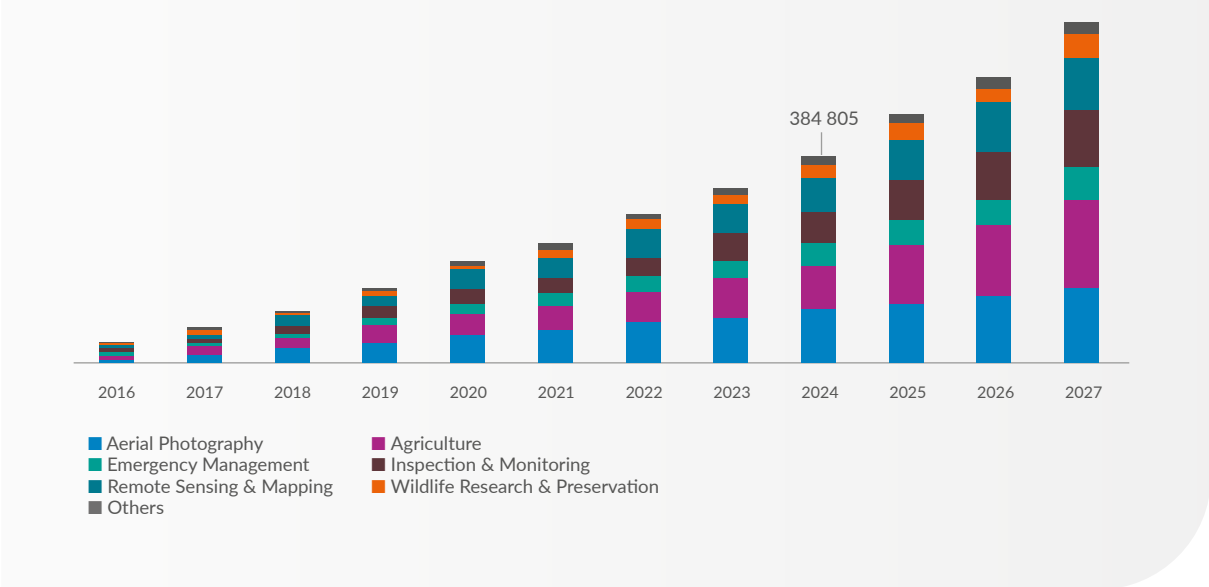
## A. What are drones?

According to Webster's dictionary, a drone is an unmanned aircraft or ship guided by remote control or onboard computers. Unmanned aerial vehicles (UAVs) are a component of an unmanned aircraft system (UAS) which includes a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator, or autonomously by onboard computers. Compared to manned aircraft, UAVs were originally used for missions too "dull, dirty or dangerous" for humans. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural and other applications, such as policing, peacekeeping, and surveillance, product deliveries, aerial photography, agriculture, smuggling, and drone racing.

The pandemic has accelerated the use of technology in many aspects, but the pre-pandemic period saw a rise in global interest for the use of commercial drone applications across a wide range of industries. However, despite the increase in the use of other disruptive technologies during the pandemic, the drone industry around the world saw a decline in demand for drones. However this trend appears to be temporary because currently the estimated value of the global market for UAV drones is 33.6 billion U.S. dollars, and it is projected to reach 58.5 billion U.S. dollars by 2026, growing at a compound annual growth rate (CAGR) of 13.9% over the analysis period.[25]

Drones are already an integral part of the international trade supply chain, pushing regulators to become more comfortable with the technology, and thereby aiding them in the development of a legal framework that determines the conditions in which they will operate. Studies indicate that the integration of drones in the trade environment can support economic growth. However, integrating them successfully and safely requires all players in the market to be prepared and engaged in the process to ensure that the supply chain can fully realize the benefits. In the trade environment, modes of physical delivery of goods are being continually re-defined. Delivering goods in remote areas where there is poor to no infrastructure is expensive, but on the other hand, even in highly populated areas where there is infrastructure, delivery is equally costly. For

*Figure 22: Global commercial market size, by applications, 2016-2027 (units)*




*Source: www.gminsights.com*

25 https://www.strategyr.com/market-report-uav-drones-forecasts-global-industry-analysts-inc.asp

that reason, suppliers are constantly looking to solve the 'last mile' problem and drones are being tested not only for domestic deliveries, but even for cross-border deliveries. Some express service providers and postal operators who tested or piloted the use of drones for parcel deliveries at the local level in nearby areas just a few years ago have turned into success stories. For example, Amazon and Alibaba have turned their interest in the use of drones into business, with Amazon working on safely and efficiently delivering packages to customers within 30 minutes or less. In early 2020, Swiss Post transported laboratory samples by drone as part of regular ongoing hospital operations. This came after completing over 2,000 test flights in May 2019.[26.]

*Integration of drones in the trade environment can support economic growth.*

Some ports are also integrating these new technologies in their daily operations. For instance, the port of Durban has undergone a pilot project that seeks to modernize its infrastructure and operations. The South African port has deployed an arsenal of both air and submarine drones to capture information, monitor, and inspect the condition of the port's infrastructure, vehicle traffic, and seabed to avoid operational risks and ensure the quality of their services.[27]

## B. Use of drones for cross-border delivery of goods

Drone technology allows a high level of autonomy. Using GPS signals for navigation and Wi-Fi for communication, some models require human operators to guide the vehicle manually by remote radio control, using on-board cameras that can act as digital eyes over several kilometres, depending on battery life. Other, more sophisticated vehicles can follow entirely pre-programmed take-off, flight, delivery and landing routines without human intervention.

Further technical benefits that trigger assumptions of increased use of those new delivery modes are related to the lower weight of unpressurized drones, leading to big drops in fuel consumption, and less noise and faster turnaround time in comparison to conventional aircraft, for instance. The Delft University of Technology designed an unmanned containerized cargo freighter, called ATLAS, that can reduce the cost of shipping by air, and the time required for inter-modal transfers and transport on the ground. The lift-generating body of the design helps to make it more fuel-efficient compared to a conventional design. Dronamics, a Bulgarian company, has successfully created and tested an unmanned drone, named Black Swan, capable of transporting up to 350 kg of cargo at distances of up to 2,500 km at nearly 80% of the cost of any other air freighter currently in use.[28] Running on 100% synthetic fuel and needing at least 400 metre-long (unpaved) runways, the Black Swan offers logistics companies the opportunity to deliver same-day services to even the most out-of-reach communities. [29]

Prototypes are now being developed of drones capable of carrying 10 to 30 tonnes (10,000 to 30,000 kilograms) of cargo that could fly from China to Europe in 12 hours with optimal fuel consumption, and which could serve airports that freighters or cargo-friendly wide body passenger aircrafts do not serve at present.

With these developments, the potential for the use of more developed generations of drones for the commercial delivery of consignments within a country and across borders at a marginal cost is not too far-fetched. Drones can play a very important role when it comes to making an urgent and efficient delivery to a remote place - be it medicines for a critical patient or an urgent spare part to a shut-down oil rig. Drones could equally be useful in first- and last-mile delivery, and thus improve and supplement the overall efficiency of

26 https://www.post.ch/en/about-us/news/2020/experts-issue-a-good-report-for-swiss-post-and-matternet-drones-to-take-off-again
27 https://maritimafrica.com/en/african-ports-the-obligatory-march-towards-digitalization/
28 https://www.dronamics.com/unveiling
29 https://www.dronamics.com/unveiling

the supply chain. The use of drones can also be expected to appear in cross-border deliveries in neighbouring countries, notably in regions which lack adequate road transport infrastructure.

## C. Regulatory issues

The successful case studies relating to drone technology for deliveries demonstrate that the application is still mostly limited to pilot projects, short-term initiatives, and prototypes. The main reason for this is that the effective use of this technology cannot be explored any further without an enabling environment. The December 2018 Gatwick Airport drone crisis that lasted for 38 hours, disrupting the flights of some 120,000 passengers, showed some of the challenges posed by this new technology. The major hurdle in this area is the unavailability of a drone policy framework for developing drone regulations. In order to operate in one common air space, a holistic approach for manned and unmanned aviation is of the utmost importance. The relevance and availability of the drone technology depend on whether the regulatory environment enables the safe use of drones and on developing a framework that will determine the conditions in which the technology will exist. Global standards on safety, privacy and data protection need to be reviewed, potentially updated and/or developed. Equally, thought must be given to developing an aeronautical data exchange, processing, and synchronization network that accounts for the unique requirements of drones, while at the same time internationally harmonizing drone regulations, potential certification standards, and operational procedures.

Some civil aviation authorities, for example in the U.S., the EU, China and the UAE, have already started developing a new set of rules and regulations related to the movement of drones. In one such proposal, a drone that weighs less than 25 kilograms and flies at an altitude of lower than 150 metres will be exempt from airworthiness certification but will still need to register with the respective civil aviation authority. Those weighing from 25 to 150 kg will have to go through airworthiness certification before they are allowed to operate. All flights performed by drones will be required to submit a flight plan before an aircraft takes off.

Another proposal under discussion is to create an airspace between 60 to 120 metres above the ground for high-speed drones to operate out of line-of-sight, while smaller, slower drones would be restricted to flying below 60 metres. A 30-metre airspace between 120 and 150 metres would be a "no-fly-zone", which would serve as a buffer between drones and conventional aircrafts. All drones would be connected to the Internet, so they could be tracked and receive warnings if they are in danger. Further, to avoid mid-air collisions, drones must be able to communicate with each other and should have the capability, like traditional aircraft, to "sense-and-avoid" another object in the air.

The International Civil Aviation Organization (ICAO) has been working on safety standards for large drones/remotely piloted aircraft systems (RPAS). The ICAO's Aviation Security (AVSEC) Task Force on RPAS recently identified numerous security challenges (including the issue of cross-border operations) that need to be addressed in the near future. These issues will be discussed at future ICAO AVSEC Panel meetings.

## D. Potential impact on Customs

*Drones are already being used by some Customs administrations for surveillance and monitoring purposes.*

The use of drones in the Customs environment no longer belongs to the "generation next". Drones are already being used by some Customs administrations for surveillance and monitoring purposes. For instance, Dutch Customs are increasingly using drones to monitor port areas and coastal regions. This involves surveillance not only to combat drug smuggling but also to provide aerial assistance during arrests. Drones are mainly used in the port area of Rotterdam, but plans are under way to use them more nationally.[30] A remote-controlled drone with a

30 https://www.dronewatch.eu/dutch-customs-are-increasingly-using-drones-to-combat-drug-smuggling/

high-definition camera for underwater surveillance has been used by Dubai Customs since August 2020. The drone can go as deep as 50 metres to perform a detailed scan of a boat. With a range of about 30 metres from the controller, it can travel at a speed of 15 kilometres per hour. Dubai Customs use the drone to inspect the wooden boats coming into Dubai.[31]

However, while there are budding opportunities for the use of drones as a mode of delivery, there are also challenges. Clearly, Customs need to monitor, analyse and comprehend emerging developments in the use of drones and related regulatory developments and come up with an appropriate policy response, together with potential adjustments of Customs procedures and requirements, where needed.

Customs can delve into these developments from two perspectives – as a user and as a regulator. In the law enforcement area, drones are seen as the next logical technological evolution. As already mentioned, Customs may potentially use drones for surveillance in inaccessible and hazardous terrains, closing the gap, if there is one, in border surveillance in those areas. Equipped with infrared and high-resolution imaging, drones can be effective in border and maritime surveillance, in particular for monitoring suspects, curbing cross-border smuggling and drug trafficking, and nuclear, biological and chemical sensing and tracking.

U.S. Customs and Border Protection have advanced the exploitation of drone data through their existing digital forensics capabilities. As drones continue to be utilized more extensively in the smuggling of illegal contraband, and in counter-surveillance by Customs and immigration officials, data retrieved from drones is becoming a necessity for both law enforcement and intelligence use. Drone data is not easily accessible like the data in traditional electronic devices used in the Customs environment. The need for ever-evolving digital forensic techniques is beyond question. Collaboration across the WCO and WTO memberships could vastly improve the pace and quality of data exploitation for everyone.

Another area to explore is the Customs regulatory perspective, and what is required to meet the current and emerging challenges, especially in the context of the potential use of drones for the cross-border delivery of legal and illegal goods. In terms of threats, drones themselves could potentially be used for cross-border air attacks. In addition to security concerns, another emerging threat is the use of drones for smuggling, including the cross-border delivery of drugs. In 2015, 12.7 kg of heroin were found to have been smuggled across the border into the U.S. using drones. In the five years following this seizure, U.S. Customs and Border Patrol have reported 170 similar drug-smuggling incidents involving the use of "narcodrones".[32]

*Customs need to monitor, analyse and comprehend emerging developments in the use of drones and related regulatory developments and come up with an appropriate policy response.*

31 https://www.thenationalnews.com/uae/2021/10/21/gitex-2021-underwater-drone-helps-dubai-customs-catch-drug-smugglers
32 https://www.businessinsider.com/how-mexicos-cartels-are-using-drugs-for-attacks-drug-smuggling-2021-5?r=US&IR=T

In 2021, Dubai Customs' drone monitoring unit spotted and seized a container in Jebel Ali in which illegal pills were hidden among spare motor parts. In the same year, Dubai Customs officials thwarted around 398 attempts to smuggle drugs into Dubai.[33]

There are several other examples. For instance, Customs officers in southern China's technology hub Shenzhen discovered a group of criminals using drones to smuggle 500 million yuan (USD 79.8 million)-worth of smartphones from Hong Kong to Shenzhen.[34] The smugglers usually operated after midnight and only needed seconds to transport small bags holding more than 10 phones using the drones. The gang could smuggle as many as 15,000 phones across the border in one night. Regulating the use of drones has become an important task for China, the world's largest manufacturer of consumer drones. Acting on tips, law enforcement officers from both sides discovered the operation in February 2018 after months of investigation. It was confirmed that the gang apprehended had been operating since 2016.

*Another area to explore is the Customs regulatory perspective, and what is required to meet the current and emerging challenges, especially in the context of the potential use of drones for the cross-border delivery of legal and illegal goods.*

Drug cartels are using unmanned drones to carry drugs across the southern border, challenging the U.S. technological ability to stop the advance.[35] Border Patrol agents are increasingly worried about the threat from drug-cartel-flown drones, after agents spotted 13 drones suspected of carrying drugs across one section of the U.S.-Mexico border in just one four-day period in November 2017. Cartels all along the border are using drones, though the San Diego sector has been among the most active in reporting on the traffic. In August 2017, the U.S. government arrested a 25-year-old American citizen who admitted he was the pick-up person. Police seized just under 6 kilograms of methamphetamine, worth an estimated USD 46,000, and also seized the drone, a Matrice 600 Pro, which sells for about USD 5,000, can take off with a 6 kg load, and can fly at 65 kph.

Heroin smugglers from Pakistan have been using drones to drop contraband into Indian villages along the Punjab border.[36] Smugglers were recently found using drones in Punjab's Gurdaspur. The report cited that a plastic bag consisting of narcotic substances was found flying at a height of 200 metres. The drone flew back to Pakistan without dropping the package after it was noticed by the police. According to the report, drug smugglers have been adopting newer methods for ensuring the delivery of narcotic substances across borders.

It is a well-known fact that untaxed cigarettes have been one of the biggest issues in the daily life of European Union Customs officers. In February 2022 the Lithuanian State Border Guard Service captured an unmanned aircraft that had entered the territory of Lithuania smuggling around 1,000 packets of cigarettes. Similar incidents were reported the previous year at the Lithuanian border with Belarus, where nine unmanned aircraft smuggling cigarettes were detained by Customs officials.[37]

These cases are a serious warning sign, and Customs must consider how it can prevent smuggling carried out with the use of drones.

During the 40th Session of the Enforcement Committee, a panel discussion elaborated on

33 https://www.thenationalnews.com/uae/transport/
34 Retrieved from https://www.chinadailyhk.com/articles/192/48/173/1522315752387.html on 3 December 2018
35 The Washington Times – 2 janvier 2018.
36 Retrieved from https://www.timesnownews.com/india/article/border-security-forces-latest-headache-pakistani-smugglers-using-drones-to-deliver-drugs-across/236762 on 3 December 2018
37 https://border-security-report.com/border-guards-took-over-a-drone-from-belarus-which-was-smuggling-cigarettes/

emerging security issues, noting that, with the development of new technologies, changes to supply chains, and threats posed by new and innovative terrorist attack methodologies, it was important that Customs were able to respond in order to protect society and to address emerging risks relating to the international movement of goods and terrorist actors. Among the new emerging threats that were addressed was the increase in the availability of drones. It was acknowledged that, whilst these disruptive technologies and new forms of commerce presented opportunities for trade, they also presented opportunities for terrorists to acquire weapons or their components.

New technologies do, however, give Customs a range of tools to address smuggling, such as the availability of geospatial data and other new data sets which provide Customs with potential new sources of intelligence to inform their risk profiles.

The March 2016 PTC had noted that, with technological advancements and increasing sophistication, drones could soon be used for cross-bor der deliveries of goods; delegates recognized that Customs was the agency responsible for cross-border movement of conveyances which included drones. In this context, some delegates had opined that, in addition to the other issues raised, some other regulatory issues related to the use of drones for cross-border e-commerce delivery to buyers/consumers directly, instead of airport-to-airport services, and control of cross-border movement of unmanned drones (as some of the existing regulatory requirements are designed for conveyances with drivers/pilots) needed to be further explored in harmony with existing regulations, and in close cooperation with civil aviation, other relevant government agencies and private sector stakeholders.

In conclusion, the March 2016 PTC had agreed that there was a need to carry out further research on the topic, in particular exploring more practical experiences and related policy developments, as well as monitoring and coordinating the work being done in this area by other international organizations (e.g. ICAO).

# 6. Virtual, augmented and mixed reality

## A. What are virtual reality, augmented reality and mixed reality?

Virtual reality, augmented reality and mixed reality are technologies that either create a fully simulated world or add digital artefacts to the physical world; both of which can be useful tools for Customs training purposes.[38] Virtual reality is on one end of the spectrum, being a fully immersive technology. On the other end of that spectrum is augmented reality, where digital artefacts are added to the physical world. With mixed reality, digital artefacts are projected in the physical world.[39] Those artefacts can interact with and exist alongside physical objects. This allows the merger of both the physical and digital worlds. The following gives further clarity to the differences between the different (immersive) technologies:

- Virtual reality fully immerses the user in a virtual environment through the use of a headset, allowing them to interact with and manipulate digitally rendered objects.
- Augmented reality projects digital objects into the user's field of vision via a mobile device or headset, keeping the user in the physical world and allowing them to be 'heads-up' and hands-free.
- Mixed reality is the fusion of augmented and virtual realities, offering the user the ability to manipulate and interact with digital objects while still being engaged in a physical environment.

Different large organizations and enterprises are developing products using these technologies to address an array of issues and challenges. While virtual reality has been commonly associated with the video game industry, it presents revolutionary applications to healthcare, product design and development, and training, and offers new ways to approach certain processes. Examples of virtual reality headsets that have been in circulation are Meta's Oculus Quest 2 and Xiaomi's Mi VR Standalone.

Both of these virtual reality devices are wireless all-in-one headsets, meaning that they do not need to be tethered to an external processor. Although the headsets have been geared towards entertainment, allowing users to enter an immersive viewing environment, devices like the Oculus Quest 2 include wireless controllers, pairing users with virtual reality-compatible video games or fitness programmes. With the device being a product of the largest social media platform, it offers new channels to connect users and allows for new ways to socialize and interact through cyberspace.

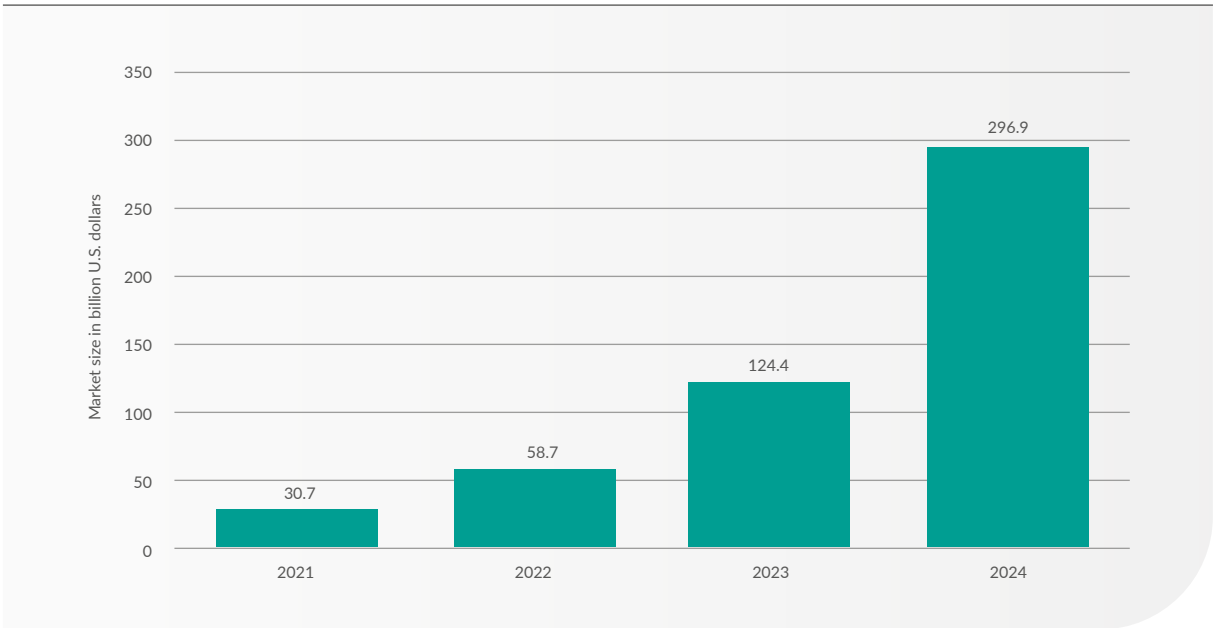
Like virtual reality, augmented reality and mixed reality products are also being developed with the intention of using them in business settings. Examples of such products are Google Glass, spectacles that also come with AR and VR capabilities, and HoloLens, a pair of mixed reality smartglasses developed and manufactured by Microsoft.

38 https://en.wikipedia.org/wiki/Immersive_technology
39 https://en.wikipedia.org/wiki/Mixed_reality

Augmented and mixed reality devices, like those used for virtual reality applications, are untethered. However, unlike VR headsets, augmented and mixed reality devices superimpose auxiliary information in the user's general field of view in a holographic fashion. This allows users to remain hands-free and 'heads-up' as they perform certain tasks. The applications of these devices are, at the moment, boundless, as they can be applied to a multitude of sectors from healthcare to education and across multiple service lines.

Over the next decade, these technologies are expected to grow exponentially as they permeate throughout different sectors, industries, and service lines. Although virtual and augmented realities will bring about varying levels of economic growth, a PWC report[41] exploring these technologies suggested that the economic contributions of augmented reality will be significantly higher than that of virtual reality by 2030.

*Figure 23: Augmented reality (AR) and virtual reality (VR) market size worldwide from 2016 to 2024 (in billion U.S. dollars)*




*Source: Statista[40]*

*Over the next decade, these technologies are expected to grow exponentially as they permeate throughout different sectors, industries, and service lines.*

40 https://www.statista.com/statistics/591181/global-augmented-virtual-reality-market-size/
41 https://www.pwc.com/seeingisbelieving

## B. Existing practices

Virtual, augmented and mixed reality are used in different industries and domains, most commonly in a learning environment. These kinds of applications are slowly growing in the Customs domain as well.

The use of virtual reality solutions for Customs training purposes has been successfully employed by government bodies like Dubai Customs, where virtual training is used to improve inspectors' efficiency in identifying prohibited items (WCO link). The virtual training programme offers inspectors the chance to hone their skills and knowledge of their duties and responsibilities in a low-risk virtual environment while following a progression system.

Other applications of virtual and augmented reality devices can be found across both the public and private sectors. For example, the Dutch Ministry of Defence uses virtual reality to simulate environments where soldiers can train in specific capabilities, e.g. shooting practice. This technology can lower the costs of training while enhancing its effectiveness.[42]

The WCO Virtual Reality Training project, which uses virtual reality to train Customs officials, was launched with financial support from CCF-Korea in 2021. Using a virtual reality environment, officers are trained through a game-like virtual container cargo inspection process. The project is based on the belief that the adoption of disruptive technologies is critical to keep pace with the latest trends and the opportunities they present to improve Customs in every way, and will continue to look for more options to enhance Customs expertise. Additional training courses on topics such as e-commerce are currently under development and will be added to the course collection. Feedback to date has been encouraging, and the continued inclusion of virtual reality courses is widely seen as the future of online training and capacity building activities.

DHL has used augmented reality to help employees find the right products when order picking.[43] Boeing has used the same technology to give instructions to employees who are assembling aeroplanes.[44]

NASA uses a prototype mixed-reality headset to transport people virtually to the Moon and to Mars.[45.] The technology is also used to view objects in the places in which they will be used, e.g. a Moon lander or Mars Rover.

## C. Potential future use in Customs and border management

There are different potential future uses in Customs and border management for virtual, augmented and mixed reality. Augmented and mixed reality can be used to project visual assistance in the physical world, e.g. when doing a physical inspection. This assistance can be in two forms. The first is general assistance that is provided in advance to all employees. The second is the possibility that the assistance is provided by someone who can see what the Customs officer sees, in real time.

Virtual reality can have a more enhanced use in training Customs officers. Different kinds of training environments, simulations, and scenarios can be created that are difficult to recreate in the physical world - the machine room of a large container vessel, for instance.

The U.S. Customs and Border Protection (CBP) Office of Trade, for example, is exploring the role of augmented reality not only for training simulations, but also to protect intellectual property rights on American imports and fill knowledge gaps that may exist between experience levels. According to a CBP publication,[46] while the application of this technology is still in progress, it is expected that Customs agents will benefit from the use of augmented reality headsets by making a library of searchable goods readily available for agents to compare and identify counterfeits with

42 *https://magazines.defensie.nl/landmacht/2017/10/10_op-missie-in-virtuele-wereld (in Dutch).*
43 *http://www.dhl.com/en/press/releases/releases_2017/all/logistics/dhl_supply_chain_makes_smart_glasses_n ew_standard_in_logistics.html*
44 *https://www.theverge.com/2016/7/14/12189574/boeing-google-glass-ar-building-airplane-parts*
45 *https://www.nasa.gov/feature/jpl/mixed-reality-technology-brings-mars-to-earth*
46 *https://www.cbp.gov/sites/default/files/assets/documents/2020-Jun/Augmented%20Reality_0.pdf*

3D renderings. Because these technologies have been integrated into headset devices like Microsoft's HoloLens, agents can perform their duties hands-free.

Extended use of these technologies has multiple applications for the public sector, and, in the realm of Customs, they can be used to perform efficient security screenings by reducing common risks and errors that can occur during regular checks.[47.] Facial and behavioural recognition software can alert Customs agents of potential risks when dealing with individuals attempting to cross borders. Other services these devices can provide are to identify and assess vehicles (e.g. warning agents if a vehicle is lower to the ground than it should be in the case of smuggling), as well as provide translating services if interacting with foreign-speaking individuals.[48]

Finally, another potential use is the visualization of big data sets. Big data is hard for a layman to visualize and manipulate. When using mixed reality, data can be projected in the physical world as digital artefacts that can be manipulated as real objects.

*Virtual reality, augmented reality and mixed reality are technologies that either create a fully simulated world or add digital artefacts to the physical world.*

47 https://www.accenture.com/_acnmedia/accenture/redesign-assets/dotcom/documents/global/1/accenture-g20-yea-report.pdf
48 https://www2.deloitte.com/content/dam/Deloitte/us/Documents/public-sector/us-fed-augmented-government.pdf

# 7. 3D printing

## A. What is 3D printing?

3D printing, or additive manufacturing, is a process of making three-dimensional solid objects from a digital file, using a 3D printing machine and raw materials such as plastic, metal, nylon, or others.

3D printing is widely used for industrial, medical, construction and consumer goods. The technology is also at the early stages of adoption within the automotive and aerospace sectors, along with some applications in the consumer electronics sector for the manufacture of cases and covers for smart phones, tablets and other portable devices.

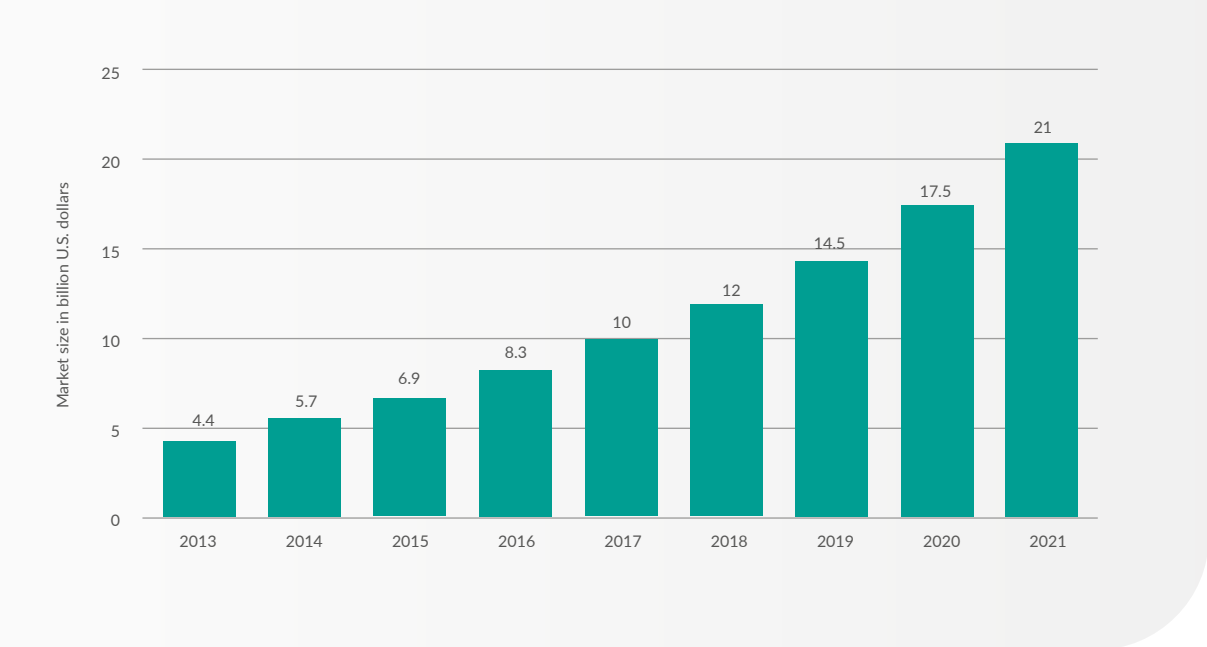
The 3D printing market is growing rapidly. In 2020, the worldwide market for 3D printing and manufacturing was valued at around USD 12.6 to 17.5 billion and has since been projected to continue growing at an annual rate of 17% up to 2023.[49] According to some reports around 1.4 million 3D printers were shipped globally in 2018, with an estimated 8 million units to be shipped in 2027.[50] As 3D printers become more affordable and capable of manufacturing more complex products, it is expected that both consumer and producer demand will rise. Consumer-friendly models are already on the market and sales of personal 3D printers have indicated growth rates of 200% to 400% from 2007 to 2011.[51] Increasing demand and vast potential applications have led some analysts to estimate that the 3D printing industry could add anywhere from USD 230 billion to USD 550 billion per year to the global economy by 2025.[52]

Although 3D printing accounted for less than 0.1% of global manufacturing revenues in 2018, it has experienced an average annual growth rate of 26.9% over the last three decades (WEF, p. 26).[53] Computer-aided design (CAD) software and the market for on-demand parts and services are expected to almost triple. Discrete manufacturing is seen as the dominant industry for 3D printing.

*3D printing is widely used for industrial, medical, construction and consumer goods.*

49 https://www.statista.com/statistics/315386/global-market-for-3d-printers/
50 https://www.statista.com/statistics/370297/worldwide-shipments-3d-printers/
51 https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/disruptive%20technologies/mgi_disruptive_technologies_full_report_may2013.ashx
52 https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/disruptive%20technologies/mgi_disruptive_technologies_full_report_may2013.ashx
53 https://www.weforum.org/reports/mapping-tradetech-trade-in-the-fourth-industrial-revolution

*Figure 24: 3D printing market size worldwide from 2013 to 2021*




*Source: Statista*[54]

Traditionally, material objects (ranging from computer chips to sweaters to automobiles) have been built in factories controlled by a single corporate entity that designs the product, manages its supply chain, produces it and sells it, directly or indirectly. 3D printing is about to kick off an era of digital transformation that will redefine such classic models.

3D printing is a technology that could upend manufacturing modes, supply chains, business models, customer relationships and even entrepreneurship itself. 3D printing could do to physical goods what cloud computing is doing to digital services; what the PC, Internet and smart mobility have done to computing; and what outsourcing has done to software development and business processing. That is, take mass distribution and innovation to the next level, while realigning the very geography of work and trade.

Technology has brought dramatic increases in industrial productivity since the dawn of the Industrial Revolution with the use of steam engines and waterpower, followed by the application of electricity, assembly lines, electronics and automation. Today, we are in the midst of a fourth wave of technological advancement – the digital industrial technology known as Industry 4.0[55] presents a transition from a centralized to a decentralized, highly flexible, personalized and digital smart mode of production and services.

In time, 3D printing could lead to a shift towards more digital and localized supply chains and lower energy use, resource demands and related $CO_2$ emissions over the product life cycle. However, full realization of the potential of 3D printing depends on overcoming a number of obstacles. The necessary material technology is still nascent and building complex objects is slow. There are also regulatory issues that need to be addressed before 3D printing can be widely adopted in the consumer market. Finally, although declining in

54 https://www.statista.com/statistics/796237/worldwide-forecast-growth-3d-printing-market/, accessed on13 January 2019.

55 Industry 4.0, also known as the Fourth Industrial Revolution, refers to the rapid and exponential technological change that has permeated throughout several industries and facets of social life. Technological breakthroughs, like AI, robotics, IoT and 3D printing, alongside advancements in quantum computing and biotechnology, have presented new opportunities and challenges for consumers and producers alike.

recent years, the cost of printers, materials and scans is still relatively high, especially for deployment in micro, small and medium-sized enterprises (MSMEs).[56]

There are nine pillars of Industry 4.0: big data and analytics, autonomous robots, simulation, horizontal and vertical system integration, the industrial Internet of Things, cyber-physical systems, the cloud, additive manufacturing (3D printing), and augmented reality. Among these, 3D printing has a crucial role.

## B. Potential impact on Customs and border management

3D printing is one of those technologies where there is no evident benefit of use by Customs. However, some believe it will have a potentially important impact on the work of Customs in the future.

Discussions on the growing area of 3D printing were launched by the Virtual Working Group on the Future of Customs (VWG FC) at the October 2015 PTC Meeting. China, as the initiator of the topic, submitted a paper which formed the basis of a very intense and fruitful discussion.

Some of the questions which were brought up included:

- is Customs the proper/legally responsible government agency in the area of 3D-printed products that are not imported/exported goods but are printed at national level (sometimes these products have been designed by an overseas company and/or the software instructions come from abroad);
- how to deal with the growing number of new economic operators: the owners of the 3D printers;
- how to safeguard IPR for 3D printing;
- how to ensure security etc.

Delegates felt that the topic of 3D printing fitted very well into the task of the PTC and the VWG FC to explore what might have a significant impact on the role and responsibilities of Customs in the future.

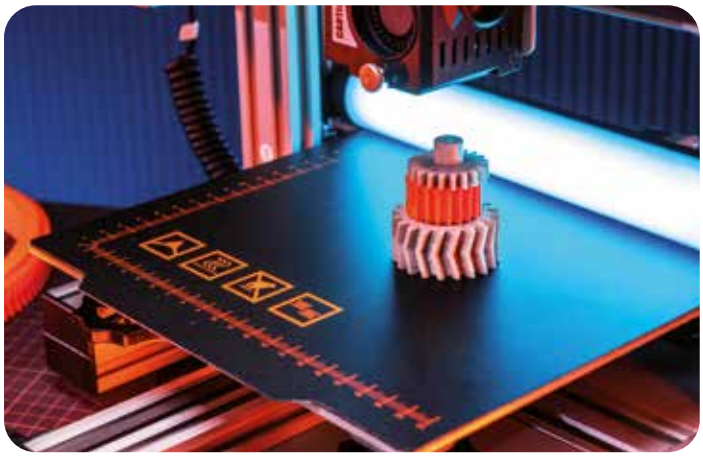
Some delegates felt that the enhanced use of 3D printing would probably have more impact on movements on the domestic market rather than across borders and that, based on current legislation, that might mean 3D printing could have more implications for other governmental agencies rather than for Customs (e.g. tax administrations, national police, etc.). Questions were raised as to whether Customs would nevertheless be involved in monitoring the virtual supply chain, and if so, how this could be achieved, including whether existing legal instruments were sufficient to cover such responsibilities. In general, the cooperation of Customs with tax authorities and other relevant agencies, possibly as a new dimension of coordinated border management, was regarded as important in this field.

Several delegates also stressed the possible implications of 3D printing for origin, valuation, IPR and security, while one Member stressed that it should not present new restrictions in cross-border trade. Other delegates indicated that there might be revenue implications, especially VAT implications and, in addition to the legal issues already addressed, there might be a need to redefine the term "goods" in the future - which might be relevant to Customs responsibilities in 3D printing overall.

Delegates felt that this topic required more research, including looking into the existing legal frameworks and tapping into what already existed, such as whether comparable experiences were already in place (e.g. related to music downloads, that could assist further).

The PTC agreed that there was a need for more research on the topic, especially regarding the legal implications, including by exploring the coverage of existing legal frameworks (such as those regarding music downloads) as well as what other international organizations (OECD, WTO etc.) were doing in this regard. It further agreed that research on 3D printing within the VWG FC would continue in the intersession and that it would report to the PTC at its meeting in March 2016.

56 *WTO World Trade Report 2018: https://www.wto.org/english/res_e/publications_e/world_trade_report18_e.pdf*



*The increase in 3D printing would accelerate the movement of raw materials and reduce the movement of finished products across borders which, on the other hand, would have revenue implications.*

In the intersession, members of the VWG FC shared relevant materials available in open source, including papers provided to the Secretariat by a number of partner organizations such as the OECD, WTO and UN OCHA. Two members of the VWG FC volunteered to develop research papers based on the available material. (These research papers are available in Annexes I and II to PTC document PC0444E1a.)

The results of the research generated forth several relevant conclusions:

- It was noted that 3D printing would subvert global trade flows and accelerate the transforming role of Customs from duty collection to social protection, mainly IPR, public safety and security. Key elements to consider included the reduction of the movement of physical goods across borders and the increase in the movement of raw materials as opposed to finished products.
- 3D printing did not present anything essentially new to current Customs rules and procedures. Instead, most of the legal issues surrounding 3D printing concerned intellectual property rights such as copyrights, patents, industrial designs and trademarks. Nevertheless, Customs was advised to keep abreast with all the new developments (technical, legal or otherwise) in the 3D printing industry. And if there was the political will, Customs should also discuss how the scope of Customs legislation could eventually be widened.

The results of the research did not intend to conclude the discussions on the implications of 3D printing on Customs; they confirmed that the answer to this question was not straightforward and that at that point it was still too early to identify how 3D printing would progress and impact Customs business in the future. However, a few main themes emanated from the two research papers:

- An important element relating to the cross-border exchange of digital files for 3D printing, referenced by both research papers, was the WTO Moratorium on the imposition of Customs duties on electronic transmissions, which dated back to 1998 and had been extended at each Ministerial Conference since then. This meant that increased exchange of digital files for 3D printing purposes across borders would not have revenue implications, at least not for the time being.
- The increase in 3D printing would accelerate the movement of raw materials and reduce the movement of finished products across borders which, on the other hand, would have revenue implications. These assessments resonated with reports looking into the potential acceleration or deceleration of trade as a result of 3D printing. A 2019 World Bank report[57] analysing 35 partially 3D-printed products found positive effects

57 *World Bank Report: https://openknowledge.worldbank.org/handle/10986/32453#:~:text=The%20analysis%20finds%20that%20trade,%2D%20and%20high%2Dincome%20countries.&text=The%20results%20counter%20widespread%20views,supply%20chains%20and%20reduce%20trade*

on trade. A 2017 report by ING's International Trade Analysis[58] team estimated that nearly a quarter of global trade could be displaced by 2060 if 3D printing replaced half of conventional manufacturing among a 1-2% decrease in physical trade by 2030, respectively. An August 2021 report by ING's International Trade Analyses team revisited its previous estimates and reassessed that by 2040, if 3D printing made up 5% of global manufacturing, this would lead to a negative growth rate of -4.5% or 0.2 percentage points less trade per year for the next two decadess.[59]

- As 3D printing becomes more widespread, disruptions to established supply and production chains will ensue and new trade trends will occur. A similar observation was made by the WTO in its 2018 World Trade Report, noting the decline in trade of digitizable goods (e.g. sound recordings, video games, and literary works) from 2.7% of total goods in 2000 to just below 1% (0.8%) in 2016 as result of the digital revolution.[60] The WTO report suggested that the prevalence of new technologies and capabilities would alter established practices and, in the case of 3D printing, demand for transport and logistics services would most likely decline, and that it would be possible to substitute production of certain goods domestically; thereby driving down trade costs. This would, therefore, lead to a cascading effect in the overall global trade system as global value chains could become shorter and reshoring practices be encouraged (see WTR2018). Ultimately, the long-term effects on global trade, whether positive or negative, however, are still too early to determine as the scope of 3D printing remains limited.
- IPR implications are seen as an important element to bear in mind. However, how this would impact Customs work was not clearly defined.
- In terms of legal implications, it was conjectured that the envisaged decrease in Customs revenue would not seem to be a strong reason for overhauling Customs legislation. Instead, digital blueprints could become taxable items, which would not necessarily impact Customs but possibly (also) tax administrations. Other national agencies, such as the police, anti-drugs and standards agencies, could be well suited to dealing with security issues relating to 3D printing.
- Finally, apart from national laws, it was noted that there were many international conventions and treaties, particularly those signed under the auspices of the WIPO and the WTO, that could contribute to the orderly management of 3D printing across the globe, e.g. the WTO TRIPS Agreement and Dispute Settlement Understanding, and the WIPO Copyright Treaty, Patent Law Treaty, Trademark Law Treaty, Washington Treaty, Paris Convention and others.

During discussions at the March 2016 PTC, diverse views were shared on 3D printing. Some delegates argued that Customs dealt only with tangible goods and that, therefore, digital transmissions should have no implications for Customs work, even though it was still important to keep a close eye on developments in the future.

Others were of the view that Customs needed to monitor the cross-border movement of intangible goods too, or to at least look into this new means of manufacturing and identify whether the same rules would apply, for instance, in de-

*The long-term effects on global trade, whether positive or negative, however, are still too early to determine as the scope of 3D printing remains limited.*

58 ING Report: https://think.ing.com/reports/3d-printing-a-threat-to-global-trade
59 https://think.ing.com/reports/3d-printings-post-pandemic-potential/
60 https://www.wto.org/french/res_f/publications_f/world_trade_report18_f.pdf

termining the origin of goods. Some delegates felt that Customs still had an important role to play in monitoring cross-border movement of intangible goods. In conclusion, the March 2016 PTC agreed that, even though for the time being no duties were being imposed on intangible goods, this did not mean that Customs had no role to play. Furthermore, it was agreed that the topic of 3D printing and its implications on Customs was not to be closed at that point in time, but was to be revisited in the light of any relevant future developments.

An item regarding the role of Customs in the taxation of intangible goods was subsequently placed on the agenda of the December 2018 Policy Commission. The objective was to discuss the issue of the imposition of Customs duties on intangible goods and provide policy orientation, given the ongoing WTO moratorium on the imposition of duties on electronic transmissions, and to consider possible approaches and associated legislative and operational requirements for the collection of Customs duties on intangible goods, to examine Customs' role in non-fiscal areas such as security, admissibility, IPR and illicit trade in the context of growing digital trade, and to provide guidance on the way forward. At the request of several delegates, it was decided not to take up this item for the time being. However, several other delegates stressed the importance of this subject and considered that a future discussion could be useful in order to have a better understanding of the role of Customs regarding intangible goods from a wider perspective. The outcomes of such a discussion would also have implications for the role of Customs in cross-border transfers of 3D printing digital files.

As a 2021 OECD trade policy report[61] noted, measurement challenges remained in assessing the overall impact of 3D printers, and suggested that the WCO's creation of HS heading 84.85 would allow for better monitoring of machines for additive manufacturing (3D printers) and their impact on trade.

There were no further discussions on this matter after the March 2016 PTC, other than those already indicated in this section. However, in relation to the 2021 OECD trade policy report, the new heading 84.85 for additive manufacturing (3D printers) was created as part of the 2022 edition of the WCO Harmonized System (HS 2022) and entered into force internationally on 1 January 2022. Once a country implements HS 2022, it will enable better national monitoring of 3D printers and their impact on trade. While many countries implemented HS 2022 on 1 January 2022, others will take some months before they have implemented the new edition of the HS and start statistical reporting under HS 2022 provisions. It will therefore take some time before international statistics on this are available but, as more and more countries implement it, increasing information on trade in these machines internationally will be accessible.

61 *OECD Report: https://www.oecd.org/publications/3d-printing-and-international-trade-0de14497-en.htm*