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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Guidelines on the environmental efficiency of machine learning processes in supply chain management

ITU-T L-series Recommendations – Supplement 42

ITU-T

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Supplement 42 to ITU-T L-series Recommendations

Guidelines on the environmental efficiency of machine learning processes in supply chain management

Summary

Supplement 42 to ITU-T L-series Recommendations provides guidelines on the environmental efficiency of machine learning (ML) processes in supply chain management. This guidance document is intended to support machine learning researchers and operators to measure and improve the environmental efficiency of ML, and other emerging technologies (e.g., blockchain, big data, 5G, etc.) use in supply chain management.

History

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FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Guidelines on the environmental efficiency of machine learning processes in supply chain management

1 Scope

This guidance document is intended to support machine learning (ML) researchers and operators to measure and improve the environmental efficiency of ML, artificial intelligence (AI) and other emerging technologies use in supply chain management. The requirements, recommended processes, best practices and other considerations regarding the measurement and verification of environmental impact/efficiency contained in this document are developed based on inputs from leading academic experts and industry leaders. These requirements provide general guidelines applicable to the use of ML, AI and other emerging technologies in supply chain management.

Other stakeholders may also utilize this guidance to gain new understanding on the environmental impacts of ML, AI and other emerging technologies use in supply chain management.

2 References

None.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

5G	Fifth Generation (of mobile networks)
AI	Artificial Intelligence
AR	Augmented Reality
BAT	Best Available Techniques
BC	Blockchain
CDP	Customer Data Platform
DDC	Data Driven Company
DSCT	Digital Supply Chain Twin
eMBB	enhanced Mobile Broadband
ERP	Enterprise Resource Planning
GCA	Global Cybersecurity Agenda
GDP	Gross Domestic Product
ICT	Information Communication Technology

IoT	Internet of Things
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
ML	Machine Learning
mMTC	massive Machine Type Communication
NFC	Near Field Communication
RFID	Radio Frequency Identification
RPS	Robotic Process Automation
SDG	Sustainable Development Goal
SSC	Smart Sustainable Cities
URLLC	Ultra Reliable Low Latency Critical Communications
VR	Virtual Reality

5 Conventions

None.

6 Environmental efficiency of machine learning processes in supply chain management

6.1 ML and AI in procurement and supply chain

For the procurement and supply chain management function of many business, the adoption of machine learning (ML) and artificial intelligence (AI) for renewal of their traditional technologies and processes (e.g., with real-time analytics or process automation) is a key factor of development and digital transformation, essential for gains in efficiency, accuracy, and strategic decision-making, that can help them build or maintain a competitive advantage.

ML and AI in procurements contribute in minimizing costs (in both overall spend and in supply chain management in particular), effective data management (optimization of collection, management, and analysis of spend, inventory, and performance/compliance data), risk management (risk exposure generated by internal factors, e.g., fraud, rogue spend, process inefficiencies, etc., or external ones, such as quality/price/contract management issues, market risks, natural disasters and pandemics, etc.). The help ensure business agility and supply chain resilience (through optimized and accurate financial data and a fine-tuned, contingency-ready supply chain that helps preserve business continuity when disaster strikes).

ML and AI solutions integrate digital enhancements that improve accuracy, security, risk management, efficiency, and strategic planning. Procurement organizations can, therefore, move beyond the limitations of traditional processes and compete effectively in the modern marketplace.

6.1.1 Data driven company

A data driven company (DDC) is able to take decisions on the basis of real information and data, rather than on personal opinions or feelings. Digital technology is also able to bring the "data-driven" approach to all company management levels (and the marketing domain is, nowadays, strictly linked to digital and web analytics).

From a technological point of view, data are taken from different sources, can be of different types (e.g., structured or not structured) and are stored and managed in a "data lake", which can be managed in a flexible and open manner. For the marketing domain, for example, the adoption of a specific customer data platform (CDP) allows the possibility of collecting and sharing real-time customer data and of analysing this data with advanced analytics or data science systems. ML and AI play a relevant role in this, and blockchain technology, with its data certification possibilities, provide a relevant contribution to supply chain management improvements (e.g., in tracking of goods and services, in order to certify the origin and source of products or services).

6.1.1 5G and supply chain

Future networks will be based on 5G, the fifth generation of mobile radio access is already under deployment and will link together different technologies, such as artificial intelligence (AI), Internet of things (IoT), AR/VR, Edge computing, etc. 5G will provide enhanced mobile broadband (eMBB), massive Machine Type Communication (mMTC) and ultra reliable low latency critical communications (URLLC). Ubiquity and high velocity data transfer will allow communication with many IoT devices, spread through companies and related supply chain environments (production, transport, final use, decommissioning, etc.), with low latencies and data availability and related management in real-time (see Figure 1). The supply chain area will, therefore, take advantage of these features, in its digital transformation [b-Not_Tec TIM].

Figure 1 – Supply chain eco-system

New technological trends will affect and contribute to supply chain evolution, as depicted in Figure 2.

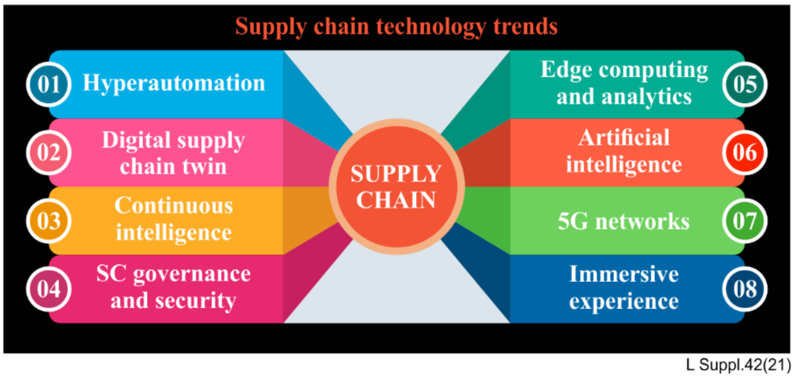

Figure 2 – New technological trends for supply chain

Hereafter the list and details of these new technology trends that will impact supply chain [b-Gartner.Trends]:

1 **Hyperautomation**: framework for end-to-end automation of company legacy platforms, going beyond boundaries of single and siloed processes [b-Automation Anywhere]. It combines robotic process automation (RPA) tools, machine learning (ML) and artificial intelligence (AI).

2 **Digital supply chain twin (DSCT)**: a digital representation of the physical supply chain. It is derived from all relevant data across the supply chain and its operating environment. That makes the DSCT the basis for all local and end-to-end decision making.

3 **Continuous intelligence**: ability to process automatically and in real-time data at a much faster pace than people can. Supply chain leaders, or other systems, can look at the processed data, understand what is happening and take action immediately [b-Forbes].

4 **Supply chain governance and security**: increasingly important macro trend, as global risk events are on the rise and security breaches impact companies on both the digital and physical levels. Use of advanced track-and-trace solutions, smart packaging, and next-gen radio frequency identification (RFID) and near field communication (NFC) capabilities.

5 **Edge computing and analytics**: in an edge computing framework, data is processed and analysed close to its collection point, with use of Internet of things (IoT) devices. It is the technology needed when there is a demand for low-latency processing and real-time, automated decision making. Edge computing is right now making its way into the manufacturing industry. For example, some organizations have adopted driverless forklifts for their warehouses. Heavy equipment sellers can use edge computing to analyse when a part needs maintenance or replacement.

6 **Artificial intelligence**: in supply chain AI provides a toolbox of technology options that help companies understand complex content, engage in natural dialogue with people, enhance human performance and take over routine tasks. Currently, AI helps supply chain leaders solve longstanding challenges around data silos and governance. Its capabilities allow for more visibility and integration across networks of stakeholders that were previously remote or disparate.

7 **5G networks**: 5G is a massive step forward with regard to data speed and processing capabilities. The ubiquitous nature of 5G boosts its potential for supply chains. For example, running a 5G network in a factory can minimize latency and enhance real-time visibility and IoT capabilities.

8 **Immersive experience**: virtual, augmented and mixed reality has the potential to radically influence the trajectory of supply chain management. These new interaction models amplify human capabilities, and companies already see the benefits in use cases like onboarding new workers through immersive on-the-job training in a safe, realistic virtual environment.

6.2 Environmental efficiency of ML/AI in supply chain management

6.2.1 Introduction

Adoption of ML, AI and other emerging technologies (e.g., blockchain, 5G, etc.) leads to huge data processing and computing demands in server farms hosting an increasing number of processing and storage systems, with related relevant environmental impacts (e.g., energy consumption, end of life and waste management of systems, etc.). The best available techniques (BAT) and recommendations for environmental impact reduction of these systems and technologies shall, therefore, be adopted, in order to achieve green supply chain management.

On the other hand, it must also be said that improvements in environmental efficiency of processes involved in supply chain management are foreseen from the adoption of ML, AI and other emerging technologies in this area. Positive effects are foreseen, for example, in optimization of goods transportation and distribution (e.g., reduction or optimizations of trucks rolls) with management of the supply chain supported by ML and AI, both on supplier and final customer sides.

In the following paragraphs the relevant references for environmental efficiency, made available from main technical standardization bodies, are listed.

6.2.2 Applicable ITU-T Recommendations

1) ITU-T Recommendations:

a) ITU-T L.12nn series on sustainable power solutions for ICT networks, specifically:

- ITU-T L.1200 *Direct current power feeding interface up to 400 V at the input to telecommunication and ICT equipment*.
- ITU-T L.1205 *Interfacing of renewable energy or distributed power sources to up to 400 VDC power feeding systems*.
- ITU-T L.1206 *Impact on ICT equipment architecture of multiple AC, –48VDC or up to 400 VDC power inputs*.
- ITU-T L.1207 *Progressive migration of a telecommunication/information and communication technology site to 400 VDC sources and distribution*.
- ITU-T L.1210 *Sustainable power-feeding solutions for 5G networks*.
- ITU-T L.1220 *Innovative energy storage technology for stationary use – Part 1: Overview of energy storage*.
- ITU-T L.1221 *Innovative energy storage technology for stationary use – Part 2: Battery*.
- ITU-T L.1222 *Innovative energy storage technology for stationary use – Part 3: Supercapacitor technology*.

b) ITU-T L.13nn series on energy efficiency of ICT infrastructures, specifically:

- ITU-T L.1300 *Best practices for green data centres*.
- ITU-T L.1302 *Assessment of energy efficiency on infrastructure in data centres and telecom centres*.
- ITU-T L.1303 *Functional requirements and framework of green data centre energy-saving management system*.
- ITU-T L.1304 *Procurement criteria for sustainable data centres*.
- ITU-T L.1305 *Data centre infrastructure management system based on big data and artificial intelligence technology*.
- ITU-T L.1310 *Energy efficiency metrics and measurement methods for telecommunication equipment*.
- ITU-T L.1316 *Energy efficiency framework*.
- ITU-T L.1320 *Energy efficiency metrics and measurement for power and cooling equipment for telecommunications and data centres*.
- ITU-T L.1325 *Green ICT solutions for telecom network facilities*.
- ITU-T L.1330 *Energy efficiency measurement and metrics for telecommunication networks*.
- ITU-T L.1331 *Assessment of mobile network energy efficiency*.
- ITU-T L.1332 *Total network infrastructure energy efficiency metrics*.
- ITU-T L.1350 *Energy efficiency metrics of a base station site*.
- ITU-T L.1351 *Energy efficiency measurement methodology for base station sites*.
- ITU-T L.1360 *Energy control for the software-defined networking architecture*.

ITU-T L.1361 *Measurement method for energy efficiency of network functions virtualization*.

ITU-T L.1362 *Interface for power management in network function virtualization environments – Green abstraction Layer version 2*.

ITU-T L.1370 *Sustainable and intelligent building services*.

ITU-T L.1371 *A methodology for assessing and scoring the sustainability performance of office buildings*.

ITU-T L.1380 *Smart energy solution for telecom sites*.

ITU-T L.1381 *Smart energy solutions for data centres*.

ITU-T L.1382 *Smart energy solution for telecommunication rooms*.

c) ITU-T L.14nn series on life cycle assessment (LCA), with specific reference to the following:

ITU-T L.1400 *Overview and general principles of methodologies for assessing the environmental impact of information and communication technologies*.

ITU-T L.1410 *Methodology for environmental life cycle assessments of information and communication technology goods, networks and services*.

ITU-T L.1420 *Methodology for energy consumption and greenhouse gas emissions impact assessment of information and communication technologies in organizations*.

ITU-T L.1430 *Methodology for assessment of the environmental impact of information and communication technology greenhouse gas and energy projects*.

ITU-T L.1450 *Methodologies for the assessment of the environmental impact of the information and communication technology sector*.

ITU-T L.1470 *Greenhouse gas emissions trajectories for the information and communication technology sector compatible with the UNFCCC Paris Agreement*.

d KPIs from U4SCC – United for smart sustainable cities:

The U4SSC (united for smart sustainable cities) developed a set of international key performance indicators (KPIs) for smart sustainable cities (SSC) to establish the criteria to evaluate ICTs' contributions in making cities smarter and more sustainable, and to provide cities with the means for self-assessments, in order to achieve the sustainable development goals (SDGs). These KPIs can be found in the Collection Methodology for Key Performance Indicators for Smart Sustainable Cities (see Figure 3).

Figure 3 – KPIs from U4SSC

From this experience and work the KPIs related to environmental topics can be taken as a reference to measure/verify environmental efficiency of machine learning processes in supply chain management:

e) ITU-T also published the following Recommendations on KPIs:

ITU-T Y.4900/L.1600 *Overview of key performance indicators in smart sustainable cities*.

ITU-T Y.4902/L.1602 *Key performance indicators related to the sustainability impacts of information and communication technology in smart sustainable cities*.

7 e-procurement platform

This clause highlights how e-procurement platforms can enable the full use of AI and BC in the optimization of supply chain management, particularly in case where it is multilingual, resulting in an optimal solution for all stake holders.

7.1 Background

7.1.1 Environmental challenge

Environmental protection is the biggest challenge that the modern world is faced with. It is imperative that we reduce carbon footprints of all facets of our lives so as to save the planet for our future generations. In recent decades we have been quite reckless with our developmental activities, at the cost of the health of the planet. In the past few years, ITU and the other international organizations have been actively engaged in taking various measures for reversing this trend. Leveraging modern technologies for mitigating these challenges is one such step. This technical report focuses, in this perspective, on supply chain management.

7.1.2 Supply chain management

In the past the supply of most of the commodities to any consumption centre used to be as localized as possible. Cost of transportation and the time taken in shifting the goods from the producers to the main markets for consumers used to be an important factor in determining where the goods should be sourced from.

However, reductions in transportation costs on account of a number of factors, and also the use of cold storage in transportation for perishable commodities, and WTO interventions that have ensured people can get even commodities such as milk, vegetables and fruits can be transported across continents, mean that markets are now global. While it might be exciting to eat apples from New Zealand while sitting in Europe, such moves have huge implications on the environment in terms of carbon footprint.

Today the question is how can such things be remedied, and what role can ITU play in this? This is where artificial intelligence/machine learning can play a role in ensuring reductions in carbon footprints by controlling the procurement system in a transparent manner.

7.2 Concept

It is proposed that an automated e-procurement system should be constructed which has the following features:

1. It is built keeping the environment in mind. The artificial intelligence and machine learning tools can be optimised in such a manner that:
   - Transportation over a long distance has an inbuilt penalty. The longer the distance from where the supplies are made, results in lesser the marks in preference for procurement.
   - Use of natural fibres for the raw materials will get preference over plastics and other materials which are a challenge to the environment.
   - Even the type of packing materials used would determine the preference. Natural fibres getting preference over one-time use plastics.
   - Quality of the product continues to be an important parameter.
2. Transparency, so that the suppliers who are not influential, and are not capable of pulling strings, are also in a position to get a fair chance.
3. Removing language as a barrier for participating in the bidding process by use of a multilingual e-procurement platform.
4. The entire process is automated with little scope for human intervention.

This concept is illustrated in Figure 4.

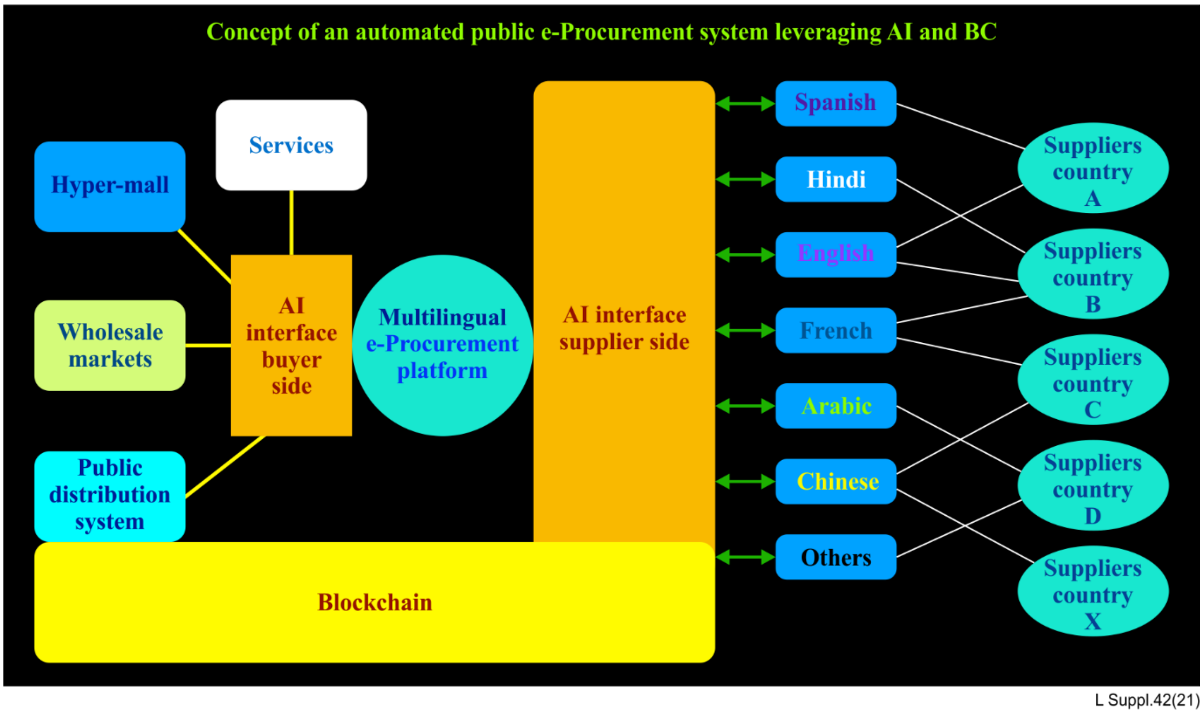

Figure 4 – Automated e-procurement system

The various components of this system are briefly explained in the following paragraphs, with more elaboration on the e-tendering platform.

Buyers side

Various types of buyers could be:

- Wholesale market for goods;
- Hyper malls for goods;
- Public distribution system for governments;
- Services for government/ private sector.

At the buyer side the enterprise resource planning (ERP) system could keep track of the consumption patterns and generate a demand on the e-procurement system in an automated way.

AI interface buyers side

This would firm up the demand and plan the goods and services to be procured based on the turnaround time in the whole chain. It would pass on a firm requisition on the e-procurement platform, in tune with the inventory management process.

e-procurement platform

This would process the entire requirement on a real-time basis, and generate a request for proposal from all the registered bidders for various goods and services. The registered bidders from any part of the globe have to meet the basic minimum qualifications to ensure:

- International quality norms;
- Transparency norms;
- Security norms.

Besides this, the e-procurement platform has to ensure:

- Factoring in of the environmental costs for each supplier location and also the raw materials used including in the packaging;

- Total integrity;
- Complete transparency;
- Multiligual – so that language does not become a barrier for the small suppliers;
- Binding the suppliers to meet their commitment, in terms of security deposits, etc. as in the conventional/ manual tendering system.

AI interface supplier side

This would ensure interface of the suppliers in their preferred language with the e-procurement system.

Blockchain

This would ensure transparency and security in the entire process, through maintenance of a hyperledger. This would be in addition to the inbuilt security and transparency functionalities of the e-procurement application software.

7.3 e-procurement platform - Need for security, transparency and integrity

The objectives of ITU-D, according to the ITU Strategic Plan, include capacity building and development. To expand the benefits of the information society to the membership in cooperation with public and private stakeholders, and to promote the integration of the use of telecommunications/ICTs into the broader economy and society as drivers of development, innovation, well-being, growth and productivity globally.

Another fundamental role of ITU is to build confidence and security in the use of information and communication technologies (ICTs). In 2007, ITU launched the Global Cybersecurity Agenda (GCA), as a framework for international cooperation in this area.

Keeping these strategic goals of ITU in view, it is imperative that improvement in the management of supply-chain can be an important driver of growth, productivity and well-being.

Within the overall supply-chain function, the "Procurement through tendering process" is perhaps the most critical, from "Integrity and Transparency" perspectives, besides directly and significantly impacting the efficiency of the supply-chain. This is important as businesses can make progress towards sustainable development goals (SDGs) of the United Nations, especially SDG-12 entailing "Responsible Production and Consumption", only if businesses have "Transparency and Integrity" in the supply-chain processes. Para-32 of the UN 2030 Agenda emphasizes the need for "transparency of action and support".

Some other relevant facts which need to be kept in mind are:

- 10% to 20% of the gross domestic product (GDP) of a country is due to public-procurement;
- Governments in various countries are shifting from manual procurement to e-tendering/e-procurement;
- e-tendering/e-procurement platforms are not standardized, and some of these could also be used for "technology-based bid-manipulation and other malpractices".

Keeping in view ITU's strategic-goals, as well as, UN's SDGs, and the facts as briefly outlined above relating to e-tendering/e-procurement, an important and relevant area for ITU to look at could be ensuring integrity, transparency, accountability and efficiency in e-procurement, through adoption of a suitable "Framework", and a "Model e-procurement system of unquestionable integrity and transparency".

7.3.1 Other aspects relating to environmental efficiency

Some other aspects of environmental efficiency that are obvious in the adoption of e-Procurement by governments for public procurement include:

- Saving in paper relating publishing of tender notices and tender documents, and the massive amounts of paper consumed in submission and evaluation of bids;
- Fuel and other costs saved due to travel and commuting relating to participation in tenders conducted through the manual process becomes redundant with e-tendering/e-procurement.

7.3.2 Focus on design of the e-tendering/e-procurement application:

Broadly, an e-tendering/ e-procurement system consists of "hosting and network infrastructure", and "the e-tendering/e-procurement application software". While the guidelines and framework for hosting/network infrastructure are well established, it is in the area of e-tendering/e-procurement application software that urgent attention is required especially if ITU enables establishment of a "Model e-Procurement system of unquestionable integrity and transparency".

In this context, some excerpts from an ITU publication entitled, *Guide to developing a national cybersecurity strategy* may be referred to:

> *5.2 Focus area 2 – Risk management in national cybersecurity: ... a risk-management approach should be adopted, as cyber-risks cannot be fully eliminated ... Importantly, for the procurement and development of infrastructure or services, the risk-management methodology should furthermore provide guidance on minimising risk through secure architecture and design, recognising that security is best achieved where it is an integral part of the design process of a product, process or service (security by design) ...*
> *... 5.2.4 Establishing cybersecurity policies: ....*
> *For example, this could include policies that address cybersecurity in procurement or development, ...*

While the above cybersecurity related prescriptions of ITU are general in nature, references to some important papers/publications relating to integrity, transparency and security, specifically in the field of e-tendering/ e-procurement are given towards the end of this clause.

7.4 Way forward

Keeping the above objectives of ITU in view, it is possible to help set up a model e-procurement platform which is multilingual, with special emphasis on security, transparency and integrity, with AI and ML being leveraged to meet the objectives of environmental efficiency.

7.5 References for e-procurement platform

Other information on e-procurement platform or more information on the discussed point can be found in: [b-e-TEG], [b-iCISA 2018a], [b-iCISA 2018b], [b-Kohli, J. 2012], [b-Kohli, J. 2015], [Kohli, J. 2016], [b-STQC 2011].

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