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Technological Innovation for Supply Chain Management

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Abstract- The application of technology in SCM has assumed new lexicons of automation, digitization, and digitalization(Schumacher, Sihn, & Erol, 2016; Swain, 2009; Zelbst, Green, Sower, & Bond, 2019). It involves leveraging various tools and platforms to move supply chain data into digital form and to transform supply chain processes and operations into fresh revenue and value-adding prospects(Ivanov & Tsipoulanidis, 2019). In modern age, technology has been widely used to transform the entire supply chain pipeline in many industries more specifically in manufacturing, communication, payment systems, customer and supplier relationship management, marketing, logistics, procurement and supply management(Hald & Kinra, 2018; Martinez et al., 2019; Sheel, 2019; Treiblmaier, 2018; Zelbst et al., 2019). The chief driver of application of technology is its implications in collaboration and communication, supply chain operational performance excellence, knowledge management, enablement of new business models and revenue streams, and security, traceability and transparency(Hald & Kinra, 2018; Ivanov & Tsipoulanidis, n.d.; Kizildag et al., 2019; Queiroz, Telles, & Bonilla, 2018).

I. INTRODUCTION

The application of technology in SCM has assumed new lexicons of automation, digitization, and digitalization(Schumacher, Sihn, & Erol, 2016; Swain, 2009; Zelbst, Green, Sower, & Bond, 2019). It involves leveraging various tools and platforms to move supply chain data into digital form and to transform supply chain processes and operations into fresh revenue and value-adding prospects(Ivanov & Tsipoulanidis, 2019). In modern age, technology has been widely used to transform the entire supply chain pipeline in many industries more specifically in manufacturing, communication, payment systems, customer and supplier relationship management, marketing, logistics, procurement and supply management(Hald & Kinra, 2018; Martinez et al., 2019; Sheel, 2019; Treiblmaier, 2018; Zelbst et al., 2019). The chief driver of application of technology is its implications in collaboration and communication, supply chain operational performance excellence, knowledge management, enablement of new business models and revenue streams, and security, traceability and transparency(Hald & Kinra, 2018; Ivanov & Tsipoulanidis, n.d.; Kizildag et al., 2019; Queiroz, Telles, & Bonilla, 2018).

Technology and Supply Chain Operational Performance Excellence

The environment of extended chains is often vulnerable to picketing, natural disasters, political instability, and market and competition linked risks have the potential to derail the resolve to reach operational excellence and resilience. Supply chain operational excellence is the inculcation of a mind-set or corporate culture of doing things better through kaizen and economic growth. It is compelled by technology (digitalization, digitization and automation) as Christopher (2005) observes: A SC's standing is comparable to the technology or information services and analytic systems anchoring it. Supply chain operational excellence employs lean and six-sigma viewpoints in achieving cutting edge leadership and greater profitability in SC operations. Ivanov & Tsipoulanidis (2019) summarised it thus;

- Aligning radical performance advancement in strategic track.
- Engendering superior customer value proposition as a maxim to help in configuring first class goods, service and processes throughout the S.C
- Inculcating the culture and mind-set of agility, adaptability and alignment
- Adoption of SC best practices including lean, six-sigma and total productive maintenance in pursuit of doing things better.

Model for Excellence in Technology Adoption in SC

Technological transformation entails adoption of intelligent factories and office operations, adaptive production and logistics networks as well as establishment of industry 4.0. In the last two decades, IT professionals have churned out a raft of revolutionary strategic technology innovations, including artificial intelligence (AI), advanced machine learning, big data analytics, the Internet of Things (IoT), Radio frequency identification (RFID), robotics, and crowdsourcing(Gurtu & Johny, 2019; Hald & Kinra, 2018; Hoek, 2019; Zelbst et al., 2019). These have great impact on security, authenticity, product provenance, confidentiality, visibility and traceability of financial and material transactions along supply and value chains (Hald & Kinra, 2018; Kizildag et al., 2019; Martinez et al., 2019). additionally, past research has mentioned cloud computing, nanotechnology, sensor technology and autonomous vehicles as having been deployed in supply chain functionalities(Cole, Stevenson, & Aitken, 2019; Schinagl & Amsterdam, 2020).

Deployment and orienting of technology strategy requires a supportive framework or model for measurement of progress in adoption scale. Ivanov & Tsipoulanidis (2019) advanced the CORRIDOR-framework to help foster establishment of technology. The framework consists of:

1. Holistic assessment of supply chain Complexity: the sophistication in supply chain environment is increasing day by day due to the ever increasing product variety, much demanding consumer, competitive pressures, and technological sophistication. There is therefore requirement for wholesome interrogation of supply chain environment and proactivity through agility, adaptability and alignment.
2. Overview of collective transparency: with globalization and extension of supply chains beyond ordinary orchestration by local firms, close monitoring has become a prerequisite. Firms should build technology capable of increasing traceability, tracking, visibility and velocity.
3. Risk and vulnerability assessment: the predictability and mitigation of real and potential technology risks and the resulting vulnerability should be top notch.
4. Understanding one's Responsibility in the SC: this comprises being scrupulous and conforming to ethical codes, behavioural standards and attaining sustainability.
5. Information availability: digital technology should be leveraged to facilitate seamless material and information flow for decision making by suppliers, producers, customers and all supply chain parties.
6. Understanding supply chain environment Dynamics: as the SC environment constantly varies in response to fluctuating customer demand, new sources, suppliers and changing components, there is need for adaptability and agility. This requires on-going systems evolution and restructuring by way of structural dynamics.
7. Restructuring the supply chain: the functions and responsibilities of teams both internally and externally must be clear and capacity development must be consciously driven.

Perspectives of Technology in SCM

In order to synthesis the understanding of technology and its application in SCM, this text granulates different SCM technological knowledge into two broad perspectives; developmental phases and key supply chain stages informed by the SCOR model(April, 2013; Ivanov & Tsipoulanidis, 2019)

The Developmental Phases of Technology in SCM

This perspective elucidates the six major improvement stages of evolution of SCM technology as:

- The three industrial revolutions
- The fourth industrial revolution-Industry 4.0
- Internet of things(IoT)
- Cyber physical systems
- Smart connected products
- Smart supply chains and smart value adding network

The Key Stages of SCM Based On the Lens of SCOR Model

Using the SCOR model, the technology can be identified and the four levels in supply chains

- Planning phase (PLAN)
- Manufacturing (MAKE)
- Sourcing (SOURCING)
- Deliver (LOGISTICS)

Technology tools applicable in each stage is listed in the table 1

Table 1: SCM Technology in Different Stages of in the Lens of SCOR Model

Digital Planning	Manufacturing	Sourcing	Logistics
Big Data Analytics Digital twin	Industry 4.0 3D printing/ additive manufacturing Virtual Reality/ Augmented Reality Robotics	e-procurement Supplier collaboration portal-VMI, EDI, SCP Augmented reality Blockchain Data and text mining Digital data management Enhanced procurement platform Identification of sourcing synergies AI SCM security rating Smart contracts Robotics	Drones or unmanned aerial vehicles Smart driverless transportation systems Smart folk lifts, pallet movers and cranes Automatic identification Communication Material handling Facility design

The Three Industrial Revolutions

The endeavour to increase efficiency, quality, volume of production and customer value has seen creation and deployment of iconic innovations and creations in the industrial stage(Ivanov & Tsipoulanidis, 2019; Roberts, 2015). The industrial revolution also marked the advanced evolution of supply chain management and recognition of its various components such as advanced logistics structures through the doctrines of work segregation. in supply chain management, Ivanov and Tsipoulanidis (2019), and Roberts (2015) summarised the first three phases of industrial revolution as:

	Industrial phase	Attributes
	First industrial revolution	Mechanization of production processes
	Second industrial revolution.	Doctrine of work segregation and electrification of production floors. This also marked the beginning of SCM through recognition of its different components and profound transformation to advanced logistics systems.
	The third industrial revolution.	Computerization of production processes in value creation. Its distinct features were the introduction electronic equipment, the proliferation of the internet and subsequently the information age, speed in communication, metadata, 3D technology, and robotics. The third industrial revolution has heightened local and globalization of trade, thus the concept “glocal”. It has revolutionised partnership and collaborative systems in manufacturing as well mass customization and automation in production. examples is the Computer Integrated Manufacturing (CIM)

Industry 4.0: The Fourth Industrial Revolution

The progresses in the third industrial revolution has birthed the era of digitalization, the fourth industrial revolution or the industry 4.0 (I4.0). Industry 4.0 is a compelling global trendsetter that is stretching the limits of industrial advancement by integrating usage of new forms of technologies to change the style of living, advancing new business models and methods of production by raving up the digital development(Cruz-machado, Alcácer, & Cruz-machado, 2019; Dalenogare, 2019; Ivanov & Tsipoulanidis, 2019). Industry 4.0 is a manufacturing and service centre dedicated to high level automation, digitalization processes, and achievement of connectivity and seamless flow of flow of information amongst electronic devices, components and human. It involves establishing intelligent systems interoperability, communications and Machine-Machine (M2M), Human-Machine (H2M) interactions that deals with data flows from intelligent and distributed systems. Rojko (2017) summarised the meaning of I4.0 as, extensive usage and specialization of IoT applied to SCM through massive application of ICT tools, connectivity, and capture and analysis of large real-time data. According to literatures, the seminal technologies that anchors industry 4.0 include;

- Cyber physical systems (CPS) production
- Blockchain
- Big Data Analytics (BD)
- Industrial Internet of Things (IIoT) and Internet of Services(IoS)
- Industrial automation
- Cybersecurity (CS)
- Cloud computing (CC) or Intelligent Robotics
- Computer Simulation
- Autonomous Robots.
- Virtual reality and Augmented Reality
- Additive Manufacturing
- Horizontal and vertical systems networking
- Smart factory
- Smart products

The conventional industrial production and I4.0 have dramatic differences. A comparative figure 2, provides distinctive differences between conventional industrial production and I4.0

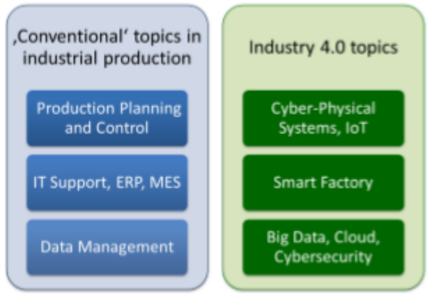


Fig. 2. Comparison of Conventional Industrial Production and I4.0 Topics (Adapted from Rojko, 2017)

Already, in more advanced countries, SC systems are applying smart systems enabled by Industry 4.0 technologies to intelligently connect machines, materials, tools and devices to facilitate mutual information sharing, prioritise operations, prompt actions and schedule work processes(Cole et al., 2019; Ivanov & Tsipoulanidis, 2019). With industry 4.0 technologies, the intervention of man in industrial and supply chain management execution is becoming less and less(Ivanov & Tsipoulanidis, 2019; Vujosevic, 2017).

Hallmarks of Industry 4.0

Based on the works of Tjahjono (2017), I4.0 can be described by four distinct features: vertical integration of smart production systems based on CPSs, horizontal integration of global value chain networks, innovative and technical improvements in design, development and manufacturing processes and acceleration of exponential technologies such as artificial intelligence (AI), robots, drones and nanotechnology. In brief, the industry 4.0 involves utilization of concepts such as(Hofmann, Sternberg, & Chen, 2019):

- Service alignment supported by CPS and the IoT and IoS
- Integrating data across technical processes and business processes in producing new business model.
- Cyber-physical systems and multi-agent system involved in decentralised decisions
- Machine-to machine, machine-to-human interoperability and multi-resource virtualization
- Capability for flexible adaptation to environmental dynamism
- Big data analytics real-time technologies

- High level flexible automation resulting in optimization of tasks.
- Digital mapping and virtualization of the actual business reality
- Smart factory comprising smart approaches of manufacturing and smart commodities.
- Usage of cloud or blockchain system that affords maximal data security.

Benefits of I4.0

According to Ivanov & Tsipoulanidis (2019), incorporation of industry 4.0 technologies have the following benefits:

i. Automation continuous improvement in SC processes
ii. Variety, customization and throughput is enhanced
iii. There is greater chance of increasing capacity
iv. Achievement of sustainability through inventory levels, transportation and emissions by integrating the lean, agile, resilience and green (LARG) supply chain
v. reduction of distortions that results into Forrester effect (Bullwhip effect)
vi. Enhanced leanness and waste reduction
vii. Provided new platform for achieving supply chain and operational excellence through reduction of supply chain risk, enhanced resilience and velocity in risk mitigation.
viii. Allows resource pooling through collaborative manufacturing, which in turn permits capability sharing and innovation, co-creation of product and services, asset mutuality and greater value addition for customers.

Reference Architecture Model of I4.0

The Reference Architecture Model of I4.0 (RAMI 4.0), a 3D model was created through cooperation of electrical and electronics manufacturing firms in Germany as a foundational lexicon and structure to buttress the implementation of industry 4.0 initiatives(Bordeleau, Mosconi, & Santa-eulalia, 2018; Cruz-machado et al., 2019; Rojko, 2017).

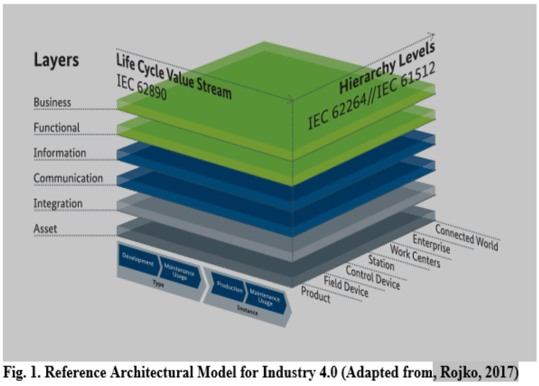


Fig. 1. Reference Architectural Model for Industry 4.0 (Adapted from, Rojko, 2017)

The 3D RAMI 4.0 should permit establishment of current standards and locate, seal or remove current gaps, loopholes and overlaps in the current standards.

The first dimension of the RAMI 4.0 tells two things, type and instance. Type of any product, machine or software/hardware is the name given to the product at the early notions, planning or concept stage, before it is realised(Zezulka, Marcon, Vesely, & Sajdl, 2016). It involves design order placement, concept development and idea testing, prototype production, testing and validation as well as preparation for serial manufacture. Upon completion of the design and the prototype, it develops to instance(Bordeleau et al., 2018; Cruz-machado et al., 2019; Rojko, 2017). The instance is a manufactured product with unique serial number which customers buy and are delivered.

On the right axis is the hierarchy level based on the IEC 62264 standard. It ranges from the location, functional ladder from product to the connected world. This is the phase of development of I4.0 system at which all enterprises, customers and suppliers is connected via IoT and IoS. The 3rd dimension of RAMI 4.0 model is to network all the aspects of the corporate digitalization and its described as follows(Cruz-machado et al., 2019; Rojko, 2017).

1. Asset Layer: comprises the tangible and the intangible aspects that must be incorporated into the virtual world through the integration layer. It includes robots, conveyor belts, programmable logical control (PLCs), documents, archives, metal parts, softwares, people and ideas(Rojko, 2017).
2. Integration layer: this layer avails the information on the assets in a digitised form to enable

computer processing, permits computer controls of the processes, produce events from the assets and enables connection with IT through elements such as sensors, RFID readers, integration with HMI, computer aided control, and actuators (Cruz-machado et al., 2019; Rojko, 2017; Zezulka et al., 2016).

3. Communication layer: it standardises communication through uniform data format and avails protocols. it provides services for control of integration layer(Rojko, 2017; Zezulka et al., 2016).
4. Information layer: this layer processes and integrates steadily available data into useful information. It receives and transforms events to match the data for the next layer. Additionally, it guarantees data integrity, steadily integrates data and receives new, quality data.
5. Functional layer: describes formal functions and develops platforms for horizontal integration of various tasks using remote access, thereby requiring data integrity. It also permits test-runs and modelling environment for services and support of business procedures. ERP functionalities belong here.
6. Business layer: the layer serves different function. It permits legitimacy and authenticity of functions in the value stream; allows mapping of business models and outcome of the overall processes; provides rules and regulatory framework and models rules pertinent to the system; creates linkage with various business procedures.

Key Technologies in I4.0

Ivanov & Tsipoulanidis (2019) grouped I4.0 implementation technology into two pillars; the networking environment (IIoT and CPSs) and enabling technology (RFID and AM). Likewise(Dalenogare, 2019), proposed a two layer framework shown in fig. 3, for classification of I4.0 technologies as; front-end technologies and base technologies. It is notable that the two classifications have albeit subtle differences as networking environment technologies are similar to base technologies whereas enabling technologies and front end technologies are similar. The front end technologies (smart manufacturing, smart products, smart supply chain, and smart working) have an end purpose application in product value chain and in meeting operational and market requirements. Smart manufacturing is the key technology here, supported by smart supply chain, smart working and smart products. Base technologies delivers the interface and the intelligence for total integration with front-end technologies. based on the works of (Rojko, 2017), base technologies provides the distinction I4.0 and other previous stages of industrial revolution.

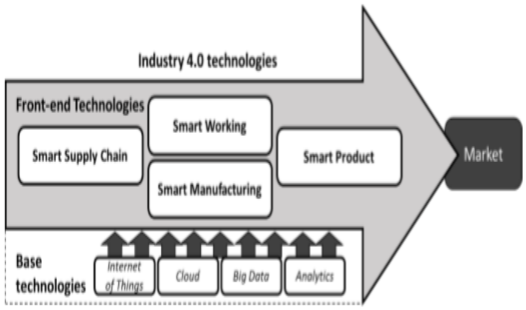


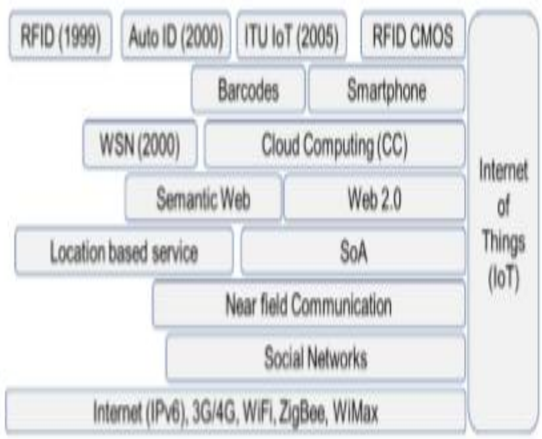
Fig. 3, Framework for I4.0 technologies, adapted from(Dalenogare, 2019)

This text will discuss the many building blocks of I4.0 implementation identified in literature(Abdel-basset, Manogaran, & Mohamed, 2018; Cruz-machado et al., 2019; Dalenogare, 2019; Leyh, Martin, & Schäffer, 2017; Motyl, Baronio, Uberti, Speranza, & Filippi, 2017). Of primary importance in attaining I4.0 objectives is teaching and lifelong professional development and access to science, technology and mathematical (STEM) skills among human resource. This will facilitate significant transformation of job and skill set of workers(Cruz-machado et al., 2019; Motyl et al., 2017).

Cooperation among corporates and higher educational institutions would be imperative in enabling development and access to STEM and subsequent diffusion of transferable skills and skill evaluation. But the question is, what teachable soft, hard, scientific and technical skills would need to be requisite for engineering students? Starting with hard skills: numerical and higher mathematical understanding, creativity and design skills, information processing, computer programmng, problem solving, investigative and experimental skills as well as knowledge of specific software tools(Abdel-basset et al., 2018; Motyl et al., 2017). In addition, there would be need for robust knowledge of industry standards, and keenness in computer operating environment for designing, simulation and testing. The indispensable soft skills include: solid analytical skills, communication skills, teamwork, leadership, and digital skills(Leyh et al., 2017; Motyl et al., 2017)

The Internet of Things (IIoT)
In IT lingo, IoT, is the linking of the words "internet" and "things". Where internet is a global interwoven networks serving users globally via interlinked computer or mobile networks using Standardised Internet Protocol suit (TCP/IP). "Things" can be any object a person or an organization. It is a network of softwares, hardwares, databases, virtual and physical objects together with sensors interconnecting and working in unison to serve people(Abdel-basset et al., 2018; Abdel-basset, Mohamed, & Chang, 2018). IoT brings together sets of technological infrastructure that integrates linked objects, facilitating their management, data mining and reach of the data they create(Rejeb, Keogh, & Treiblmaier, 2019).

Communication is enabled anytime, and anywhere between Thing-to-Thing, Thing-to- Human and Human-to-Human inside the IoT when there is internet connectivity and digitalization of all physical things(Abdel-basset et al., 2018; Cruz-machado et al., 2019). The supportive technology in IoT are(Cruz-machado et al., 2019; Rejeb et al., 2019): computer servers, mobile devices, connectivity with RFID, GPS, GPRS, GIS, Wireless Sensor Networks (WSN), actuators, middleware, Cloud Computing (CC), IoT application softwares, and Software Defined Networking (SDN). These technologies perform range of jobs, including sensing activities, movement and position, and environmental (whether) conditions; actuating and collecting; processing; storing and data exchange. Presented here below are the technologies associated with the IoT.



Within the SCM cycle of source, make, deliver and return, the application of IoT is summarised in the table.

Source	Make	Deliver	Return
planning source actions using EDI and VMI Virtualization of SC activities using IoT tracking and tracing products through their life cycle using virtual control systems integration of data for product assortment smart supply chain	factory visibility management of innovative production network smart design and product control systematic design of virtual factory	warehousing - collaborative warehousing using networked system, increasing security and safety of SC order and inventory management : shared information and inventory accuracy using RFID tags, seamless ordering using EDI and VMI transportation: accuracy and timely delivery, visibility, route planning through simulation	e-reverse logistics, optimising procurement, pricing, product recovery and strategic return acquisition.

Abdel-basset et al.(2018) posits that the ultimate result of the application of IoT in manufacturing and SCM is smart system with profound characteristics such as:

1. Instrumented: machine generated information
2. Interlinked through smart things and IT systems
3. intelligence and optimised performance via optimal large scale decision making
4. Automated: digitalization and virtualization of all resources.
5. Integrated: cooperation in all supply chain stages.

6. Innovative: dramatically new values for meeting new needs.

IoT Configuration

The configuration of the IoT architectures discussed is an abridged version of the four layer framework by (Cruz-machado et al., 2019) and the three and five layer architectures by (Sethi & Sarangi, 2017).

1. The sensing layer/ perception layer: this is the object or physical layer. Is meant to sense the "things" with inimitable parameters and connect it to the system. It also senses physical objects or smart devices in the vicinity(Sethi & Sarangi, 2017). The key devices here are actuators, sensors, RFID tags etc.
2. Network Layer and Transport Layer: the network layer connects the sensing/ perception layer to other smart devices/ things, networks and servers. It establishes and traces "things" automatically, permitting connection of all "things" and facilitates information sharing and exchange. Transport layer is the supportive infrastructure for carrying and conveying the captured information from the sensing layer and back using media such as wireless, 3G, LAN, Bluetooth and RFID.
3. Service layer (processing/application layer): It uses middleware technology to support services and applications necessary for users and applications. It ensures interoperability among dissimilar devices. It performs such important services as information search engine and communication, information storage, and sharing and management of data from the transport layer. Its key technologies are databases, cloud computing, and big data algorithms and modules. The application layer describes the various objects suitable for deployment of IoT such as Smart homes, smart cities, smart health, smart farms etc.
4. Interface layer/ business layer: interconnects and manages the whole IoT system including: "things", operational and profit model as well as user security. It provides display or broadcast and permits vivid and coherent and logical interaction of users and the system.

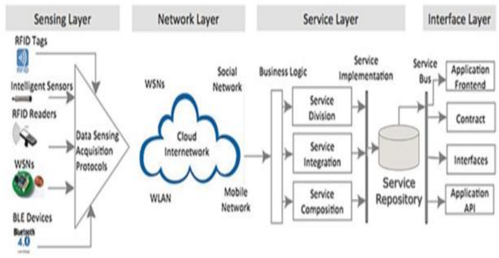


Fig. 4. General Service oriented Architecture for IoT, adapted from (Cruz-machado, Alcácer, & Cruz-machado, 2019)

Applications of IoT in SCM

The Application of IoT comes with application of its technologies in everyday supply chain physical resources and processes such as finished goods, equipment, pallets, tools, office equipment and other appliances. IoT data analysis and automation helps firms to build capabilities for predictability and agility in operations. The inter-linkage of different sets of hardware and software permits data capture. This is critical in identification of human and environmental (temperature, humidity, vibration, and air current) affecting SC operations. IoT avails three distinctive characteristics pertinent to supply chains in attaining novelty and creative opportunities for SC parties. These are: context, omnipresence and optimization. Context is the ability to monitor and interact on real-time basis and aiding immediate response to situations under control. Omnipresence is suggesting the ubiquitous nature of technology and its extensive applications among supply chains and functions. Optimization is the precise functionalities and features that each physical object possesses.

There are diverse technologies used in SC. however, the dominant ones being RFID, Wireless Sensor Network (WSN), middleware, cloud computing, and IoT software(Rejeb et al., 2019; Sethi & Sarangi, 2017). RFID technology, using a RFID tag has many applications in warehousing, manufacturing and transportation. A RFID tag may be passive, semi-active or active. A passive RFID device does not have power source. It depends on wireless radio waves (UHF) emitted by a reader or an antenna to recognise a physical object or an article it is attached to even when out of sight. A semi-active RFID device contains power source and emits sporadic indications to a network when moved or when a valuable object/asset it is attached to is moved. Active RFID device have a power source and transmits a live beams or beaconing to a network.

RFID devices attached to IoT, uses WSN to provide real-time monitoring of environmental (temperature, humidity, light intensity or velocity) and logistics activities through smart sensing capabilities. This real-time data conveyance contributes to greater data granularity leading to better supply chain resource allocation and decision making. Middleware collects and stores data from connecting layer, thus permits ready availability and access of data to the SC staff for analysis and decision making. Data universality and access is engendered by cloud computing. This aids in organizing supply chain data and information among heterogeneous and separated supply chain parties, subsequently laying foundation for greater supply chain collaboration. By aiding machine-to-machine and human-to-machine interactivity, the outcome is continuous processing and timely information transfer.

The specific areas in supply chain that will benefit immensely from IoT are inventory and warehousing operations, production and manufacturing operations, and transportation operations. IoT has ushered in an era of smarter inventory management where primary procedures of warehousing are improved, labour cost and human inefficiencies minimised and fulfilment time shortened. The embedding of IoT fused devices and tags onto carts, pallets, storage shelves and carrousels provides guidance and direction to pickers and packers, thus creates efficiency and speed in inventory location and fulfilment, and eliminates waste due to manual efforts and error. Significant savings can be accrued and error eliminated via automation and deployment of RFID and Barcode systems at receiving, docking and cross-docking spots to cut collection, recording and retrieval of data time and enhance readability accuracy. The table below provides a summary of IoT value in inventory management and warehousing management.

Inventory Management and Warehouse Operations	
Enablers	Processes
• Smart racks • Smart glasses • Monitoring cameras • Smart forklifts • Smart warehouse management system (WMS)	• Route optimization, elimination of in-process collisions • Fast, cost-efficient, and flexible operations • Better handling of items that are hard to reach or 'dark assets' (i.e., items that are difficult to detect on the shelf or racks) • Real-time visibility of inventory levels • Avoidance of stockouts • Agility and fast responsiveness to inadequacies (e.g., misplacement of items) • Workspace monitoring (e.g., for security purposes) • Stock keeping units (e.g., pallets) recognition and localization • Simultaneous threat detection and scanning for imperfections

IoT application in production and manufacturing entails embedding industrial equipment, machines and tools with sensors and smart instruments like smart microcomputers, microcontrollers, microprocessors and smart sensors for real-time monitoring and control. IoT linkage can enhance asset utilization, planning and scheduling, process capacity, set-up time, and throughput. It improves leagility by identifying opportunities for saving, quick error identification and predictive maintenance. Moreover, it engenders supply chain cooperation and value co-creation. This is summarised below.

Production and Manufacturing Operations	
Enablers	Processes
• Embedded machine sensors • Machine analytics	• Real-time condition monitoring • Remote maintenance • Predictive maintenance: Detection of physical stress levels, pile-ups, and prevention of failures • Improved measurement of throughput, setup-time, and overall productivity • Enhancement of both machine-to-machine and machine-to-human interactions

In transportation, IoT, provides many benefits. The potential for IoT is captured by smart transportation management system (smart TMS). The GPS, GPRS and GIS are leveraged to optimise route planning, flexibility and efficiency in transport operations. Transportation visibility and vehicle location identification can be enhanced through fleet management system, an IoT enabled by GPS, GPRS, GIS and other connected sensors. Conditions like temperature, humidity, lighting as well as driver and driving style can be captured through process mapping, traffic data collection and analysis. Additionally, IoT devices can provide data for improvement in forecasting of delivery time, load planning, fleet availability, and route efficiency. When combined with other technologies, it can have greater impact on green and social sustainability. This summarised below.

Transportation Operations	
Enablers	Processes
- GPRS sensors - RFID sensors - Routers - GPS satellites	- Continuous visibility of products along the supply chain - Real-time shipment tracking - Remote product sensing (e.g., temperature, humidity, vibrations) - Protection and preservation of product quality - Improve activity bottlenecks and outdoor traffic, transport mobility, road and driver safety - Maximizing fuel efficiency and optimize routing strategies - Improved service delivery

Cyber Physical System (CPS)

Technology has always endeavoured to create smart autonomous physical objects capable of safe and dependable operations. Being smart means these physical objects are connected to a network of computational and intelligent systems via sensors and actuators. In many supply chains today, the cooperation of physical processes and the cyber (computational core) is imperative. This is the cyber physical system, a system that networks the physical world with the digital world.

cyber physical system is a hybrid and heterogeneous system in which physical or engineered objects are highly intertwined into networking and information technology through transducers in order to control and monitor the physical world safely and reliably(Burns,Greer, Griffor & Wollman, 2019; Chen, 2018). It is a system where the functioning of the physical devices are examined, orchestrated, controlled and integrated by a computing and communication core(Chen, 2018). The predominant CPS constituents are: physical/ engineered devices, objects and world; transducers (sensors, actuators); information technology systems (network, communication system, and computation, analysis and control systems). In summary, a cyber-physical system is the integration of computational elements into the physical (thing) or networking of mechanical or electrical system with software component. In comparison with the IoT, the two could be equivalent, or there exists partial overlap between them or they are a subset of one another.

Components of CPS

The components of a CPS system can be classified as:

- Physical
- Logical
- Transducers
- Human

Physical Components

The physical component is the identifiable distinct object or part of the physical environment of interest to the user in meeting set goals. I can be any object, physical environment, human, cars, logistics or supply chain resources/assets, computers, electrical appliances or characteristics of open environment (obstacles, temperature, frictional surface, people, etc)

Logical Components

Are the software components, hardware apparatus, communication and network systems as well as information levels.

These comprises information technology and the equipment or interlinked systems or subsystems used create, convert, duplicate, automate capture, store, analyse, evaluate, manipulate, manage, move, control, display, switch, interchange, transmit, receive and broadcast data/ information. Also included here are: electronic content, including email, electronic documents and Internet and Intranet web sites; telecommunications products, such as video communication terminals; computers and supplementary equipment, like external hard drives; software, including operating systems and applications; information kiosks and transaction machines; videos; IT services; and multifunction office machines that copy, scan and fax documents.

Transducers: these are made up of sensors and actuators. Sensors gather information from and about physical state of systems for actions in logical processes and actuators acts as response to logical system outputs. Actuators apply energy to alter the physical state of the system.

Humans: Humans can fall in the two realms of CPS components.

Cyber Physical Systems Applications

Cyber physical system has had applications in many areas such as: education, environmental observatory, agriculture, transportation, medical monitoring and control, and energy management. Moreover, it has found application in process controls, security, smart cities and homes, and smart manufacturing. In agriculture, it is used in increasing food production know-how using technologies such as precision agriculture, smart water management, and smart food distribution. CPS competences for consistency and proactivity in scanning environmental factors and impact control. It can also be used to design solutions for pest and rodent control.

advanced and intelligent transport technologies embedded with smart sensors, communication systems(WSN, cellular, satellite systems), computational and control systems have provided real-time information sharing with consequent improvement in safety and security, volume, synchronisation and traffic management(Chen, 2018). Transport systems in many cities needs to employ intelligent transport management systems such as autonomous vehicles, smart intersection systems, wireless interactivity for vehicle-to-vehicle (V2V) and vehicle-to-infrastructure systems.

Smart, Connected Products/ Devices

Smart devices are intelligent physical products that are not connected. These devices have higher degree computational power with innate user interface. They render the advantages of efficiency, speed and precision. They include transportation containers capable of monitoring and controlling weather elements, smart bulbs, and smart refrigerators.

Smart connected devices on the other hand are engineered mechanical or electrical smart products embedded with connectivity elements capable of linking to internet networks via connectivity types such as Bluetooth, LTE (Long Term Evolution), wifi or wired. Smart connected devices comprises three constituent elements: physical element, smart element and connectivity element.

Physical element is the mechanically or electronically engineered physical device itself. For instance, transportation container cases, vehicles, pallets, shelves, cranes, etc. Smart element connotes sensors, microprocessors, data storage capability, controls, software, operating system and advanced digital user interface. The smart elements embedded in the physical product infuses the intelligence or smartness in the physical product.
Connectivity elements are embedded ports, antennae, and protocols that supports cyber existence between the physical device and the virtual world through connectivity types such as Bluetooth, LTE (Long Term Evolution connectivity), and WIFI or wired. Examples of connected devices could be smart transportation containers that can generate load manifest, record and communicate load weight, temperature, communicate with the shipper or consignee and can use facebook or twitter.

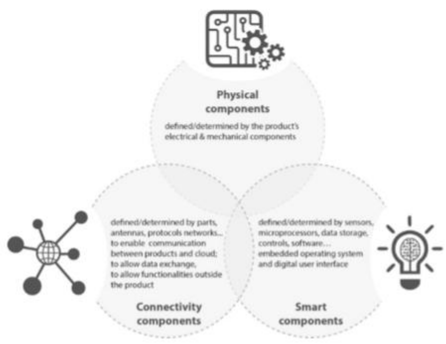
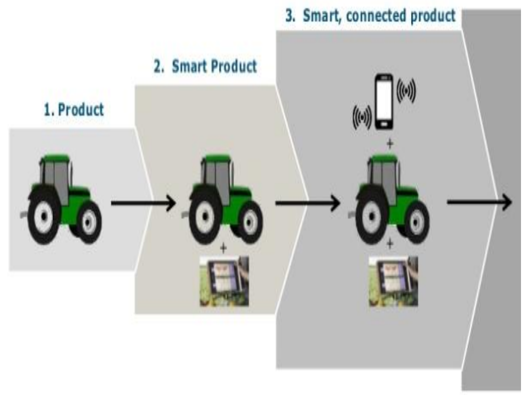
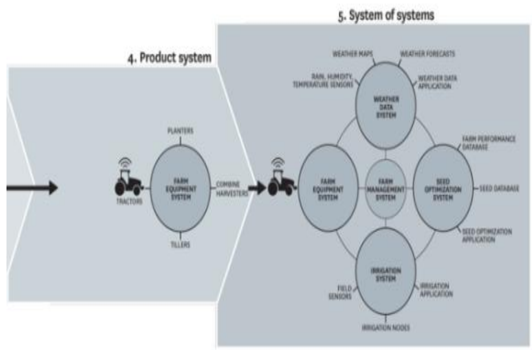


Fig. 1. The idea if smart, connected device. Adapted from(Heppelmann, 2014).

Progression from physical products to smart product to system of systems.





Functions of Smart, Connected Products

There are four groups of proficiencies of smart, connected products that have been identified in literature(Heppelmann, 2014). These are:

1. Monitoring
This functionality is operationalized by sensors and other external data bases that observes;

a. Product's conditions
b. The surrounding environmental elements
c. Functionalities and performance of the product
d. Warnings and fluctuations

2. Control
The software built into the product on in the cloud allows regulation of product's roles and customization of user experiences

3. Optimization
Monitoring and control capabilities allows algorithms that optimise product operations and functions for:

a. Enabled product performance
b. Permission of predictive diagnosis, service and repair

4. Autonomy
Combined monitoring, control and optimisation enables:

a. Autonomous product operations
b. Self-coordination of operations with other product systems
c. Autonomous product advancement and customization
d. Self-diagnosis and service

Big Data Analytics (BDA)
In today's data centred corporate scene, big data implies the massive volumes of data (reaching up to Petabyte=1024 Terabyte or Exabyte= 1024 Petabyte) that is produced and pours in from all ubiquitous sources, and manipulated by firms' systems on daily basis(Ivanov & Tsipoulanidis, 2019; Mohammadpoor & Torabi, 2019; Nguyen, Gosine, & Warrian, 2020; Pham, Nguyen, Huynh-the, Hwang, & Pathirana, 2020). These data comes in form of structured, semi-structured and unorganised written content as well as videos, images and audio-multimedia form(Sivarajah, Kamal, Irani, & Weerakkody, 2017) This provides data analysts with rich opportunity to discern meaning and use this data in the many functional areas of organizations. The points of collection these extensive quantities of data are: enterprise resource planning (ERP) systems, heterogeneous operational environments, ordering and shipment logistics, social media sites, customer buying patterns, and product lifecycle patterns(Fosso et al., 2017; Govindan, Cheng, Mishra, & Shukla, 2018; Wamba, Akter, Edwards, & Chopin, 2014). Moreover, the literatures have also identified automatic identification technologies such as global positioning systems, radio frequency identification's track and trace, mobile devices and cloud based surveillance video and sensors systems as sources.

In order to particularise the phenomenon of big data, its, numerous characteristics have been presented in literature using different dimensions. The identified dimensions that characterise big data in 5Vs are: application (volume, velocity, variety), authenticity/legitimacy (veracity), and cost-benefit relation- value(Govindan et al., 2018; Nguyen et al., 2020; Wamba et al., 2014). Other characteristics of big data include, granulated and uniquely indexical, relationality, variability, scalability, exhaustivity and extentionality(Nguyen et al., 2020).

Volume: shows the extensiveness and voluminous nature of BD. Data volumes ranging from terabytes to exabytes and occupies vast storage spaces or comprises enormous number of records(Pham et al., 2020; Wamba et al., 2014).

Variety: that is produced from multiplicity of sources and formats (structured, semi-structured or unstructured text, images or videos) and contains multidimensional data fields(Pham et al., 2020; Wamba et al., 2014).
Velocity: the speed and frequency of data production or delivery(Pham et al., 2020; Wamba et al., 2014).

Veracity: data authenticity, legitimacy and predictability through robust management of data replication problems(Wamba et al., 2014).

Value: rendering efficient and worthy insights, and driving beneficial impacts through data mining and analysis(Wamba et al., 2014).

Importance of Big Data

the following benefits of big data has been discussed in literature(Govindan et al., 2018; Wamba et al., 2014):

i. Provides opportunities for better and speedy decision making for the benefits of customers
ii. Helps improve supply chain configuration and orchestration for supply chain cost efficiency, risk management and resilience.
iii. Innovative technologies such as RFID has been used to orchestrate optimal inventory policies.
iv. Enhanced effectiveness in logistics planning, manufacturing planning and scheduling
v. Big data enabled cloud computing has been proposed as key to management of carbon foot print in heterogonous supply chain components
vi. Facilitates predictive maintenance
vii. Big data methods and technologies can be used in mitigating bullwhip effect, facilitate multi-criteria decision making, engender sensor based predictive maintenance, forecasting and demand management, and planning and scheduling.

Applications of big data

i. In retailing to improve revenue, margins and market share through price optimization modelling. This modelling combines pricing trends, various costs and inventory data to determine prices that maximise turnover and profitability.
ii. In procurement processes, manufacturing shop floors, product promotion, route optimization, real-time traffic flow management, and proactive safety management.
iii. Quality control, dynamic vehicle routing, in transit inventory management in logistics, order picking, warehousing inventory control, risk management and disaster avoidance, quick repose and facilitating LARG supply chains.

e-procurement

e-procurement integrates digital technology and purchasing procedures and resources to create the foundation and amass the benefits of strategic procurement(Sánchez-rodríguez, Martínez-lorente, & Hemsworth, 2020; Smart, 2010). Indeed, the BCG posit that 45% of the fortunes 500 firms in their yearly report, have found e-procurement tools and modules to be absolutely critical in achieving the following benefits(Aboelmaged, 2005; Brandon-jones, 2011; Doherty, Mcconnell, & Ellis-chadwick, 2013; Harrigan, Boyd, Ramsey, Ibbotson, & Bright, 2008; Sánchez-rodríguez et al., 2020): improved profitability, compressed procurement cycle, reduction in value loss, efficiency in ordering and payment management, veracity in procurement proceedings and improved accuracy and data quality(Sánchez-rodríguez et al., 2020). Moreover, e-procurement could offer significant savings in material cost, greater productivity and innovation, quality, agility and adaptability to dynamic situations, risk mitigation, and procurement resilience(Högel, Schnellbächer, Tevelson, & Weise, 2018). The power of e-procurement would be expected to further aggregate the sources and reduce spend with external vendors, engender collaborative and cooperative buyer-supplier existence, automate the requisition to pay cycle, optimise buying, accelerate processes and workflow, support tendering and enable procurement effective via the WWW(Smart, 2010).

e-procurement is therefore, the use of world wide web, internet powered commerce and electronic tools and technologies in integrating, managing, automating, optimising and permitting acquisition activities in a firm(Aboelmaged, 2005). The connotation is that e-procurement facilitates acquisition of products and services and orchestrates their flow into the organization through computer, information and internet infrastructures and systems.

Summary of benefits of e-procurement adoption (Piotrowicz, 2010)

Paper	Benefit category 1	Benefit category 2	Benefit category 3	Benefit category 4
Attaran (2001)	*Strategic* Purchasing consolidation, lower buying price and better service Freeing human resources Faster response to changes Improve chance to win new business	*Operational* Better financial control Less paper work Improved auditing and security Shorten delivery time Eliminate time-zone limitations Reduce inventory Maximise labour Data re-entry elimination	*Opportunity* Better company image and relationships On-time and correct delivery to the customer, fewer delays and errors	
Bartezzaghi and Ronchi (2003, 2004)	*Increased market efficiency* Reduced supplier searching and selection costs	*Increased supply process efficiency* Leaning procurement process Aggregating demand Internal efficiency improvement Delivery performance improvement Operative and inventory cost reduction	*Increased process effectiveness* Quality Degree of innovation Time-to-market Service level Stock-outs reduction	*Cost reduction* Negotiation Supplier searching Material costs
Bendoly and Schroenherr (2005)	*Variability reduction* From ERP product Common database Standardised human-computer interface – shorter processing time ERP process effect Business procedures rationalisation – less uncertainty regarding execution Simplified user training	*Bottleneck reduction* From ERP product Process time tracking and bottleneck reduction Standardised human-computer interface – short time required for transaction ERP process effect Business procedures rationalisation – easier bottleneck identification, fewer processes	*Waste reduction* From ERP product Monitoring of different waste types Standardised interface – easier comparability with other departments ERP process effect Business procedures rationalisation – elimination of unnecessary and waste-generating processes and sub-processes Training/education of users – more workers have ability to recognise waste-generating processes	
Croom (2000)	Operational Administrative costs reduction Improved audit and increased procurement control, greater visibility Consolidation, supply base reduction Transparency Real-time data access	Strategic Strategic advantage Increase in internal service level Improved information transparency		
Croom and Johnston (2003, 2006)	*Cost efficiency* Transaction costs Shorter processing time Purchase price reduction Internal process cost improvements: electronic transmission, single point of data entry, fewer errors Lower handling and warehousing costs	*Process compliance* Improved budgetary control Robust processes performance Transparency and data accessibility Systems reliability assured compliance to process Improved management information	*Internal customer satisfaction* Increased employee satisfaction Responsiveness Flexibility Care Reliability Integrity Competence Security	
Gebauer and Shaw (2004)	*Increased operational efficiency* Bottle-neck elimination and faster processing Improved employee productivity Delays reduction	*Increased operational effectiveness, including flexibility and emergency handling* Better communication Increased control Shorter response time		
Hawking *et al.* (2004)	*Cost-related and tactical* Price reduction Reduction of administrative costs Reduced operational and inventory costs Enhanced inventory management Improved contract compliance Shortened procurement cycle Increased accuracy of production capacity	*Strategic* Improved visibility of customer demand Better market intelligence Enhanced decision making	*Non-classified* Improved visibility of supply chain	
Sriram and Stump (2004)	*Purchasing cost* Value of buffer stocks Frequency of stock-outs Inspection/quality costs Ordering costs	*Order processing time* Order-processing time Purchase lead time Length of the planning cycle	*Purchasing process improvements* Order-processing accuracy Order-processing reliability Timeliness of deliveries Early detection of non-compliance by vendors	*Relationship quality* Mutual trust Overall coordination Frequency of disputes Information sharing
Subramaniam and Shaw (2002)	*Intermediate measures* Lower transaction costs Lower inventory Lower buying price	*Performance measures* Higher process quality Lower total procurement costs Increased user satisfaction Increased system responsiveness		

Ageshin (2001)	Increased product customisation and build-to-order capabilities, increased collaboration, use of the single system
Bartezzaghi and Ronchi (2003)	Reduce transaction costs, improve internal procurement process efficiency, increase collaboration with suppliers, lead time reduction, process improvement, process automation, reduce cost of purchased goods
Davila *et al.* (2003)	Transaction costs reduction, shorter purchasing order fulfilment time, shorter purchasing cycle time, reduced number of suppliers, lower prices paid for goods, reduced head count to support purchasing transactions, increased flexibility, more up-to date information about order, increased control on spending
Falk (2005)	Increase of labour productivity
Gunasekaran and Ngai (2008)	Better staff utilisation, efficiencies increment, help to achieve supply chain management, improved existing markets, increased customer service level, increased customer satisfaction, increased market share, reduced inventory levels, reduction in maverick buying, reduction in operational tasks, reduction in processing time, reduction in transaction costs, support for environmental issues
Lin and Hsieh (2000)	Process improvement, shorter delivery time, less administration, purchasing consolidation, time zone elimination, faster information flow, less inventory, better buyer/supplier relationships, maximising labour by empowering employees
Muffatto and Payaro (2004a, b)	Better information management, increased flexibility, reduced lead time, increased system reliability, increased process efficiency, elimination of manual procedures, better control, fewer mistakes, warehouses optimisation, procurement consolidation
Tanner *et al.* (2008)	Reduction of purchasing price, optimising total cost of procurement, internal process optimisation, securing supplies, maintaining quality guidelines, increase in cost transparency, B2B process optimisation, minimising warehousing costs, reduction of the number of suppliers, product development with suppliers
Tatsis *et al.* (2006)	Price decrease, reduction of administrative expenses, inventory reduction, shorter cycle times, improved communication and information flow, improved planning and control, improved collaboration with suppliers

e-Procurement Transactional Structures and Infrastructure

The key structural and technological infrastructural elements that propagates and governs procurement transactions were laid by Croom and Brandon-Jones in their seminal work in 2001, "Key issues in e-procurement: Procurement implementation and operations in the public sector"(Croom & Brandon-jones, 2016; Mahdillou & Akbary, 2014). The common exchanges identified by Croom includes; public web, trading sites (Exchange), market place, company hub and extranet. Croom (2001) and Rajkumar (2001) further identified the key IT infrastructure for e-procurement as: ERP/data base management systems(DBMS), emails, money transfer technology, electronic data interchange, pre-intrnet, cloud technology, wireless sensor networks, intranet, middleware, portals, and GPS. The transactional structure components are illustrated in Fig. 1

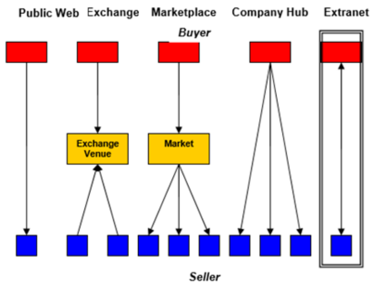


Fig. 1: Various e-procurement transaction structures, adapted from(Croom & Brandon-jones, 2016)

Public Web

These are typical public world wide web search engines (Yahoo.com, google.com or bing) or dedicated trading search engines from where a buyer can find a prospective vendor, peform market study, and place orders using online mechanisms, emails, telephone or fax(Croom & Brandon-jones, 2016).

Exchange

Exchanges are business to consumer (B2C) and business to business (B2B) e-commerce direct and reverse auction service platforms such as ebay, amazon, alibaba, vitumob, jumia etc.

Market places

It is an online or LAN enabled access market for multi-supplier and multi-products using on e-catalogue. Its hosting and maintenance is done by a third party company. Common market places in

Kenya include; Jumia market, Jiji.co.ke, Kilimall, Pigiame, tuuze.co.ke, jiji.co.ke, checki motors.

Company Hub
This is a multi-supplier and/or multi-product e-catalogue hosted and maintained by the buying company for the purpose of direct acquisition and permitting e-reverse auction and disposals.

Extranet
This is a highly secured, safe and effective e-collaborative and data sharing system enabled by linkages such as electronic data interchange (EDI), Pre-internet and cloud technology. It permits customised sharing of procurement documents, information and knowledge such as scheduling, and specification data with dedicated customers and suppliers.

It is a protected or private internet and telecommunication technology based network that shares procurement information or operations via secure systems with suppliers, customers and other entities. The illustration in Fig. 2 would suffice.

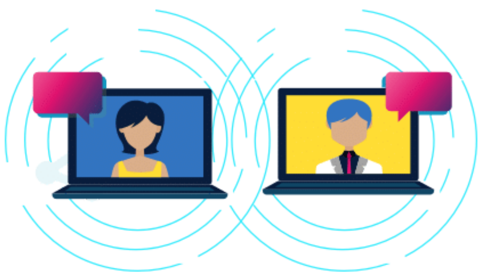


Fig. 2, extranet linkage through cloud

Advantages of extranet
- Enables more secure, effective and sequestered collaborative communication with dedicated partners.
- Consolidates and integrates supply chain processes Reduce costs by making relevant documentation like manuals available online to all the relevant parties.
- Improves and consolidates partnership relationships
- Simplifies internal business processes by permitting convergence of interactivity.
- Security of a firm's documents, information and knowledge.
- Facilitates work flexibility by allowing staff to work remotely or from home. This provides greater value, especially during the restrictions imposed by the COVID-19

The Disadvantages of an Extranet
- Requires heavy initial financial outlay for construction, implementation and staff training.
- Non-personalised service offerings may affect supplier-buyer loyalty.
- Security concerns may affect the perceived legitimacy, authenticity, confidentiality and veracity of work output.

e-Procurement Modules or Platforms
An e-procurement platform is expected to deliver functionalities that include:
- Electronic data interchange which refers to inert-organizational information system using structured data exchange protocols usually through value added networks.
- e-sourcing involving ways of identifying new sources of supply using internet technologies.
- e-tendering, the process of inviting offers from suppliers and receiving their responses electronically.
- e-reverse auctioning. Using internet technologies, bidders usually bid down the price of their offer against those of other bidders until no further downward bids are received.
- e-auction disposal. Using internet, technologies for on-line auctions of items for disposal.
- e-informing. Use of internet technologies for gathering and distributing procurement related information.
- e-collaboration. The collaborative procurement related planning and design using facilitating technologies.

8.7 Facilitators/ Critical Success Factors Influencing Success of Adoption of E-Procurement Initiatives in Public Procurement
- End-user uptake and training,
- Supplier adoption,
- Compliance with best practices for business case/project management,
- Systems integration,
- Security and authentication,
- Reengineering the process,
- Top management support,
- Performance measurement,
- Change management,
- E-procurement implementation strategy, and

- Technological standards.

1. End-User Uptake and Training

As E-procurement includes new technologies and changes in traditional procurement approaches, the need to train staff in procurement practices and the use of E-procurement tools are critical to the success of an E-procurement initiative (WB, 2003). End users can realize the immediate benefits of the E-procurement system once they understand the operational functionalities. This means that training should be given a high priority, alongside the need for public sector agencies to identify the skills required by all those engaged in procurement. As technology alone does not ensure successful adoption, the success of a public sector E-procurement initiative depends on users and buyers making use of the new process and system. The solution must attract end users to view E-procurement as the preferred means by which to purchase goods and services (KPMG, 2001). The success of the project also depends on communication to the users. According to the CGEC (2002), the two major obstacles to increasing support among users are their level of technological awareness and acceptance, and their willingness to change long-established internal business processes. As the implementation process develops, periodic user satisfaction surveys may identify the possible need for additional training (OSD, 2001).

2. Supplier Adoption

E-procurement implementation success is closely related to early supplier involvement. It is important to demonstrate the proposed solution to the suppliers and discuss any necessary changes, issues, and concerns such as various options in developing and maintaining supplier catalogues. According to the OSD (2001), providing opportunities for suppliers to offer their feedback will allow the public procurement department to monitor areas for improvement and adjust practices accordingly. Because many suppliers may be unwilling to conduct business electronically with public sector agencies because they are unclear about the benefits to be gained, they might see E-procurement as a means by which public sector agencies will simply attempt to force down prices (ECOM, 2002). Suppliers, therefore, should be educated on the E-procurement benefits that can be provided to them through a process of consultation as early as possible in the project.

3. Compliance with Best Practice for Business Case/Project Management

E-procurement initiatives only deliver the planned benefits if the users and buyers make changes to the way they work, which requires championing the project and senior management sponsorship. Specifically important, but also challenging, is ensuring “buy in” (Birks et al., 2001). Birks et al. (2001) suggest that the business case processes for E-procurement should include identifying drivers, understanding the starting point, benefits, approaches, affordability, risks, and benefit realization. To ensure achievement of the E-procurement objectives, the implementation project should proceed, as far as possible, in alignment with the business case.

4. System Integration

It is important to determine the level of integration required between the E-procurement solution and existing information systems (KPMG, 2001). The CIPFA report reasoned that if integration issues are complex, it is more likely that underlying business processes within an organization should be changed or adapted. It is also critical to link the E-procurement system to the financial management system to facilitate the process of online payment to suppliers (WB, 2003). Purchase transactions carried out through an electronic ordering transaction support system have to be reflected in an agency’s financial management systems and communicated to suppliers for fulfilment

5. Security and Authentication

Because of the sensitivity of the government data and the legal nature of orders and payments, security of data is critical in E-procurement systems. The system must have mechanisms for identifying and authenticating the user who places an order so that the supplier knows it is safe to fulfill the order. In an E-procurement environment, Birks et al. (2001) relate the security requirements at the E-tendering stage to authentication, arguing that E-purchasing systems and processes need protection because they involve a financial transaction and may be vulnerable to fraud. Stenning & Associates (2003) highlight the need for transactions between different systems to be exchanged in secure ways with absolute assurances regarding the identities of the buyers and suppliers. To encourage buyers and suppliers to engage in E-procurement, it is critical that both parties have complete confidence and trust in the underlying security infrastructure.

6. Reengineering

The Process E-procurement should be viewed as an enabling mechanism to make the process of procurement more efficient in terms of cost, time, and achievement of value for money. Where existing procurement practices and procedures may contradict the goals and objectives of the new initiative, the implementation of E-procurement will require the reengineering of existing purchasing processes (KPMG, 2001). Birks et al. (2001) suggest that roles and responsibilities might change substantially with the introduction of a new process, requiring staff to adapt to the new requirements. According to the Stenning & Associates report (2003), as a significant proportion of the benefits to be gained from implementing E-procurement initiatives are related to the changes made through process reengineering rather than the implementation of the E-procurement initiatives themselves, existing processes for dealing with procurement will have to be revised.

7. Performance Measurement

The continuous measurement of the key benefits is regarded as vital to the successful delivery of the business case. Measurement drives behaviour and is a key to making the change a success (Birks et al., 2001). Establishing goals and baselines is very important. According to CGEC (2002), a general lack of measurement capability ensures management has only limited tools for assessing organizational progress. It is important to define key performance indicators (KPIs) early in the process to enable successful benefits tracking and distil the business case into measurable KPIs. These KPIs should then be monitored throughout the project.

8. Top Management Support

There is little doubt that senior management leadership is critical to the success of an E-procurement implementation. The top management team (steering committee) must involve the project manager, any consultants working with the committee, and agency staff to develop an implementation strategy (ECOM, 2002). In this regard, considerable attention and support have to be provided by senior management to ensure that the procurement reform has been well understood in the agency. Furthermore, the executive management team is responsible for setting the vision and goals, bringing about collective commitment for change in process and organizational structures, and formulating the policies and strategies necessary to put an E-procurement initiative in place (WB, 2003).

9. E-Procurement Implementation Strategy

The creation of documented and executable strategies prior to the deployment of the E-procurement solution is an important CSF. This notion is further supported by the OSD report (2001) findings that as the procurement strategy is intended to provide savings enabled by the technology, E-procurement should be procurement driven as well as technology driven. Therefore, a clearly defined E-procurement strategy not only emphasizes the importance of E-procurement in the public sector but takes into consideration major institutional changes from the procurement process perspective as well as from the organizational perspective (WB, 2003). Another report notes that the E-procurement strategy should be based on the introduction of sound procurement practices while taking into account the differences in requirements of the public and private sectors (DOF, 2001)

10. Communication Standards

E-procurement requires various buyer–supplier systems to exchange information and electronic documents. This requires common standards. It seems that there is agreement emerging on the adoption of eXtensible Markup Language (XML) as the basis for standards (S&A, 2003). The XML standard defines the content in communication and in the selection of general data formats (KPMG, 2001). In defining E-procurement requirements, Birks et al. (2001) claim a key concern is the standard for formatting electronic catalogues. The World Bank (2003) suggests that developing an E-procurement system in an open environment allows it to link to other systems for interoperability and simplifies upgrading the system. According to the DOF (2001), successful introduction and adoption of E-procurement in the public sector also depend on the ease with which procurement related data can be exchanged both within the agencies and between their supply bases.

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