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Artificial Intelligence and Internet of Things enabled Circular economy

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--ABSTRACT--

A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models. The new dimensions of product development and reuse concept in circular economy would also significantly increase the operational facility and network complexity. In this line, Internet of Things is a new emerging technology along with artificial intelligence is proposed to overcome the challenges in circular economy concept

KEYWORDS; -IoT, Artificial intelligence, Machine learning, Big Data, Blockchain and Circular economy

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I. INTRODUCTION

Growth by trashing the planet is never a clever idea and hence re-usability is catching up fast leading to circular economy. Make, usage and disposal shaped up the “Linear model” throughout the human history millennia. Linear model or economy (LE) in which only virgin materials flow into the system or value chain to transform into value addition.It is estimated that the current global Municipal Solid Waste generation levels are approximately 1.3 billion tonnes per year and are expected to increase to approximately 2.2 billion tonnes per year by 2025 [1]. This represents a significant increase in per capita waste generation rates, from 1.2 to 1.42 kg per person per day in the next fifteen years. On the other hand, according to the latest international report, the world has disposed staggering 44.7 million metric tonnes of e-waste in 2016. That’s the weight of almost 4,500 Eiffel towers, and equivalent to 61kg of e-waste thrown away per person in 2016 [2]. As per the report – The Global E-waste Monitor 2017 is going to increase by 17 per cent to 52.5 million metric tonnes by 2021. The report showed that very little about 20%, is being recycled.

With rising global energy consumption, rapid depletion of natural resources, environmental impact and other social consequences have alerted policy makers and governments to re-think the current socioeconomic system. Hence it becomes increasingly clear that the linear economy model is no longer sustainable because of excessive energy usage, erosion of ecosystems and increased waste generation. Concerning these threats and disadvantages of LE, the circular economy (CE) is recommended by global policy makers as an alternative model. A circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life [3]. As the CE is a sustainable model whereby components and raw materials involved in the value chain is continuously recycled and restored however this model poses a completely new challenge to resolve without which it will become an expensive model.

In this paper we are discussing about the circular economy and current challenges, we discussed emerging technologies such as Internet of Things, Artificial Intelligence, Blockchain, Big data analytics, Quantum cryptography to augment circular economy and the benefits of implementing technologies in circular economy

II. CHALLENGES AND LIMITATIONS OF CIRCULAR ECONOMY

CE model has numerous advantages such as materials reuse, regenerative, environmental sustainability, control of rising resource costs, etc. [4, 5]. when compared to LE principles and the economic benefits of circular economy into viable business model is estimated to be worth more than one trillion dollars in materials savings. The transformation from linear economy to circular requires huge collective efforts by governments, policy makers and industries. Although CE is a sustainable business model, often the CE model is arguable, as the material recycling cost heavily to restore or renew. In 2017 It is estimated that 2.37 Bn smartphone users in the world and expected to reach 2.87 Bn users in 2020 [6]. Smartphone manufacturers are reducing the lifetime of a smartphone to increase their profits, on the other hand smartphones contain toxic and valuable chemical elements and metals that can be potentially recycled. However, the current product design and process is not aligned to CE concept. Major manufacturing revamp and individual cultural change are required to incorporate CE model in the society. Only a few companies such as Puzzlephone, [7]Fairphone [8] have designed smartphones complying to CE concept with disassembly facility where each component can be replaced whenever the fault is identified, and hence effective product re-cycling and life cycle of a smartphone could be improved. Another classical example of CE is automotive industries Nissan, Tesla and Renault are started to lease batteries to electric vehicles (EV) users on pay per use business model. Those batteries are then being repurposed to store electricity produced by renewable energy sources, where they can have a much longer life cycle. At the end of their life cycle, batteries will be disassembled, and their still good components will be used for new ones [9]. Other industries such as municipal waste management, Computer and Laptop manufacturers, Clothing, Footwear etc. [10] also started using CE concept to enhance the socio-economic benefits.

However, CE workflow infrastructure in emerging and existing industries requires additional attention and would also generate more challenges such as asset management, new supply chain, and establishing logistics with unfamiliar waste products and design for manufacturing service & quality control. The design for manufacturing, Service & quality control aspect will also increase the complexity in CE workflow. For an instance, an electronic PCB system might have some parts which outlast other components, in this case outlasting elements have to be designed to disassemble and reuse them in for future applications. However, in conventional LE, electronic manufacturing is well a matured industry operating at very low cost and re-usability (In other words CE) workflow and detachable provision for certain long-life chipsets or devices have not been included due to additional cost incurred during the production. To mitigate certain issues associated componentor device or product re-usability in CE, it is mandatory to understand the customer needs aligned with CE and therefore Quality Function deployment (QFD) is an efficient tool to design a product that has re-usability function. Quality Function Deployment is a systematic approach to design based on a close awareness of customer desires, coupled with the integration of corporate functional groups [11]. Companies such as Qubitor Singapore [12] and Integral France [13] have also contributed to CE model by converting waste heat into electricity using nanostructured thermoelectric devices (TED). TED as modules are attached on heat emitting sources to harness electricity using specially designed semi-conducting materials. However conventional TED manufacturing process has not taken CE into consideration when a TED module fails. The new dimensions of product development and reuse concept would also significantly increase the operational facility and network complexity. Materials or products used from consumer segment is designed to reach the mainstream of CE workflow as shown in Figure 1

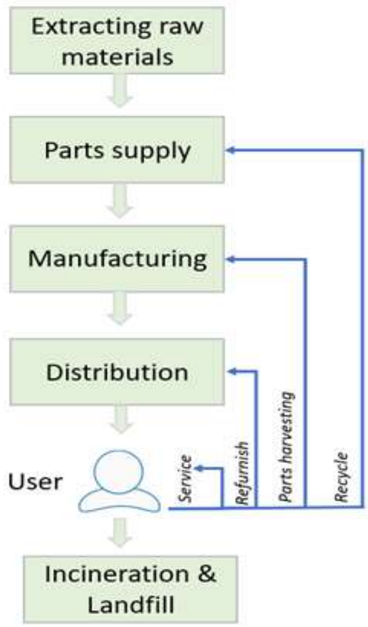

Figure 1: Depiction of Circular Economy

III. INTERNET OF THINGS (IoT) AND ARTIFICIAL INTELLIGENCE (AI)

Gartner, a leading analyst firm, estimated that 21 billion devices will be connected to internet by 2020 [14]. Internet of Things in the industrial world is becoming a buzzword in which information and communication systems are invisibly embedded in the environment around us. According to research firm IDC, via the Wall Street Journal, the IoT market could nearly triple in the coming years. In 2014, the global IoT market was worth $655.8 billion, but it could reach up to $1.7 trillion by the year 2020 [15].

The new era of manufacturing is centered on Internet of Things (IOT) for machines and processes to better monitor and control them. The machine to machine communication, machine to operator control and machine to management information are made possible with industrial IOT with high speed communication and information technology.

The IoT implementation is accelerating now among smart manufacturing industries. An IoT can be characterized as a vast number of connected industrial systems that are communicating and coordinating their data analysis and actions to improve performance and benefit society. Though industrial automation is nothing new and many companies have already automated the machine to improve efficiency, industrial IoT has been triggered by the spread of internet, falling cost of connectivity and data processing

A classical Internet of Things (IoT) system is the network of physical objects-devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity-that enables these objects to collect and exchange data. IoT combines in a single paradigm three different visions, namely Things-oriented, Internet-oriented and Semantic-oriented. The Things-oriented vision points out that every object can be monitored using pervasive technologies. The Internet-oriented vision emphasizes the ability of the objects to interact among them through the network, making them "smart." The last vision (i.e., Semantic-oriented) is related to the huge amount of heterogeneous data collected by several available sensors. This data needs to be processed to overcome the interoperability issues and the use of semantic technologies is necessary as shown in Figure 2

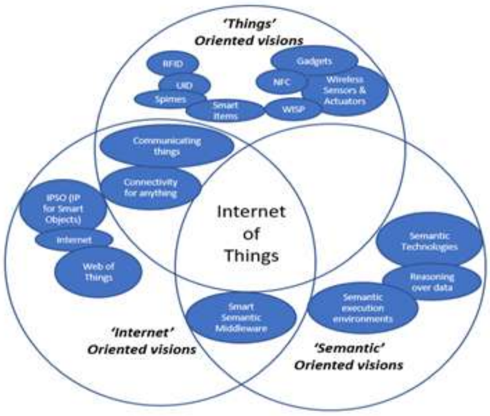

Figure 2: IoT as convergence of three different visions

III a) Practical IoT applications

IoT applications enable device-to- device and human-to-device interactions in a reliable and robust manner. IoT applications on devices need to ensure that data/messages have been received and acted upon properly in a timely manner, for example IoT-based system for Restaurant food waste in Suzhou, china. Together with a team of engineers developed an IoT-based system covering the entire Restaurant Food Waste (RFW) collection-transportation-disposal process to enhance the Suzhou City government's capacity to manage this vital urban system effectively [16]. IoT has transformed into industrial IoT (IIoT) to influence industry 4.0 by enhancing the operational efficiencies through automation, connectivity and analytics [17]. Major industries such as ABB, Airbus, Boeing Amazon, Bosh etc. [18] have started using IIoT concepts to integrate into their existing operations by employing commercial IIoT software platform developed by Hitachi, Intel, Microsoft etc. [19]. IoT has not only influenced industries, but also extended to change the individual lives by providing smart home solutions and has landmarked in various domains such as agriculture, healthcare, wearables, automotive etc.

III b) Open challenges in IoT development

The technical IoT Internet of Things architecture is shown in Figure 3, where connected things and devices will enhance utility and the ease of use for the end user. This interconnection will be intelligent due to the devices and objects being contextually aware of their environment. All of this will be achieved, provided companies are able to overcome the developmental challenges and streamline the process associated with the Internet of Things as listed below.

a) Data management challenge - The current architecture of the data center is not prepared to deal with the heterogeneous nature and sheer volume of personal and enterprise data [20]
b) Data mining challenge - Data consist not only of traditional discrete data, but also ofstreaming data from digital sensors in industrial, automobiles and electrical meters [20]
c) Privacy challenge - IoT continues to gain momentum through smart home systems &wearable devices, confidence and acceptance of IoT will depend on protection of users' privacy [20]
d) Security challenge - IoT devices havevulnerabilities due to lack of transportencryption, insecure Web interfaces, inadequate software protection, and insufficient authorization[20]
e) Chaos challenge - A small error or mistake does not bring down a system; however,in a hyper-connected world, an error in one part of a system can cause disorder throughout. [20]

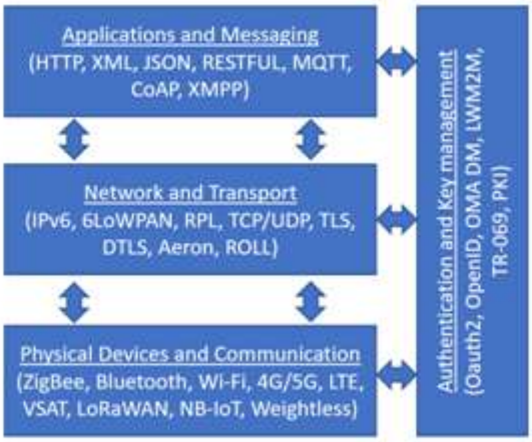

Figure 3. Technical IoT architecture

III c) Blockchain and big data analytics

IoT devices have many applications that are designed to make life easier and simpler. Engineers will be able to access a device, perform remote diagnosis and remediating any issue. However, such as advanced transformation brings new challenges in IoT development other than above mentioned open challenges such as i) Insecure web interface access [21] ii) Insufficient Authentication/Authorization [21] iii) Insecure Network Services [25] iv) Lack of Transport Encryption [21] and v) Big data management [20]. Such threats would easily introduce huge hurdles on IoT development pathway. On the other hand, emerging / disruptive technology such as blockchain and big data analytics could mitigate the IoT developments. In this line, Blockchain (BC) is a new, emerging, secured technology has been envisioned by industries and research community to major role in managing, controlling, and most importantly securing IoT devices. In general, Blockchain technology as shown in figure4 could provide a simple infrastructure for two devices to directly transfer a piece of property such as money or data between one another with a secured and reliable time-stamped contractual handshake. The blockchain uses elliptic curve cryptography (ECC) and SHA-256 hashing to provide strong cryptographic proof for data authentication and integrity. To enable message exchanges, IoT devices will leverage smart contracts which then model the agreement between the two parties. This feature enables the autonomous functioning of smart devices without the need for centralized authority. If you then extend this peer-to-peer transaction to human to human or human to objects/platforms that results in a fully distributed trustworthy digital infrastructure. Blockchain also ensures secure communication, for example conventional IoT protocols such as HTTP, MQTT, CoAP, RPL, 6LowPAN are not secured enough and heavy, complex, requires additional computation and complicated with centralized management. With blockchain enabled secure communication by wrapping the IoT protocol within other security protocol such asDTLS or TLS and therefore lightweight, decentralized, authentication and secured communication is achieved.

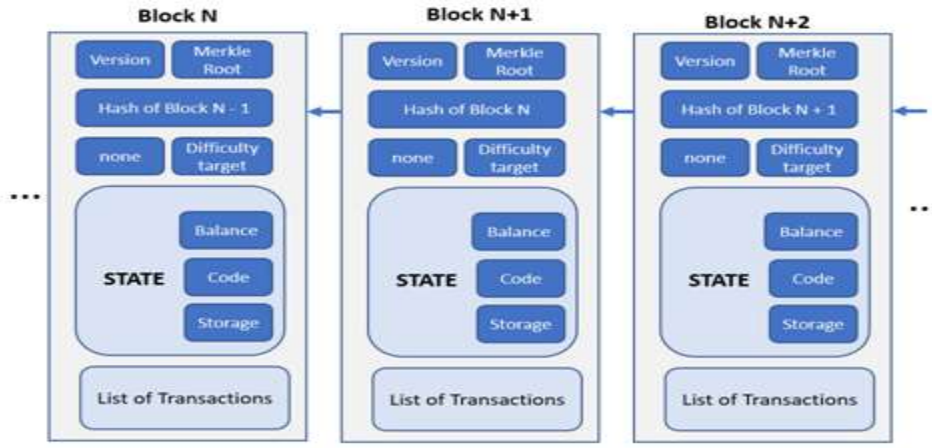

Figure 4: Blockchain design structure showing chained blocks with header and body fields

IBM Blockchain, for instance, already allows to extend (private) blockchain into cognitive Internet of Things. In fact, ultimately it will be the combination of AI, IoT and blockchain that will prove most interesting across industries by changing digital infrastructure from analytics to security [22].

III d) Quantum Cryptography

To enhance the security capability of IoT, Quantum cryptography (QC) has been explored as the existing advanced cryptographic algorithms are unable to process since the low CPU cycles and low effective encryption. QC is based on the fundamental and consistent principles of quantum mechanics. QC involved in 20th century, is based on quantum mechanics and on the Heisenberg Uncertainty principle and the principle of photon polarization. Later the concept of QC was developed by Charles H. Bennet and Gilles Brassard in 1984. QC does not transmit any message signal instead it is only used to produce and distribute a key. This key could be created depending on the number of photons reaching a recipient and how they were received. Polarization of the photons can be done at various orientations, and these orientations can be used to represent bits containing ones and zeros. A user can suggest a key by sending a series of photons with random polarizations. The representation of bits through polarized photons is the foundation of QC, known as quantum key distribution as shown in Figure 5. In case if the key is intercepted, this can be detected without any consequences, since it is only a set of random bits and can be tossed out. The sender can then transmit another key. Once a key is received securely, this can be used to encrypt a message, transmitted by communication means like: telephone, e-mail. [23]

It is expected that in future quantum computers will be available for computing applications using quantum technology. Addressing the security issues associated with IoT, hence it is believed QC can be implemented at different levels of IoT frame to establish secured network. Security is the major concern that has been anticipated by the IoT industry,however corresponding countermeasures have also been initiated and explored from adjacent technologies typically blockchain and quantum encryption.

Figure 5: Steps of secure key establishment process

On the other hand, “data” from the IoT increasing enormously, In 2012 EMC and IDC estimated that the Digital Universe would double every two years to reach 40 zettabytes (ZB) by 2020. Future of IoT will trigger massive amount of structured, unstructured, real-time, images, videos, information data into the cloud network. The staggering amount of data needs to be stored, processed and hence it is a critical challenge to process data when it is still in motion and extract valuable information from it.

Big Data Analytical tool coupled with Artificial intelligence will be employed to derive conclusion, examine raw with the purpose of finding patterns by deep learning algorithm. For example, understand the information/data from the sensor / things connected and running through several data sets to look for meaningful correlations between each other to positively impact businesses as shown in Figure6

Google, Microsoft, IBM have started offering big data Analytics platform to enable organizations to make better decisions as well as verify and disprove existing theories or models. According to Forbes, the big data analytics market will surpass $200 billion soon [24].

A good example of this in practice is video camera manufacturer GoPro. The company is using data from its products to make business decisions that improve the customer experience and pinpoint gaps in the market rather than presuming customers use products in a certain way, GoPro turned to its event processing and analytics clusters to cut through the mass of data and identify how users valued its cameras for photographs as well as video. This has led to a range of innovations and new features to help manage and curate photographs. [25]

Artificial intelligence enabled big data analytical tool coupled with data compression could revolutionize the IoT industry and move at the edge for real-time decision making. In a nutshell, IoT is the senses, Big Data is the fuel, and artificial Intelligence is the brain to realize the future of a smart connected world.

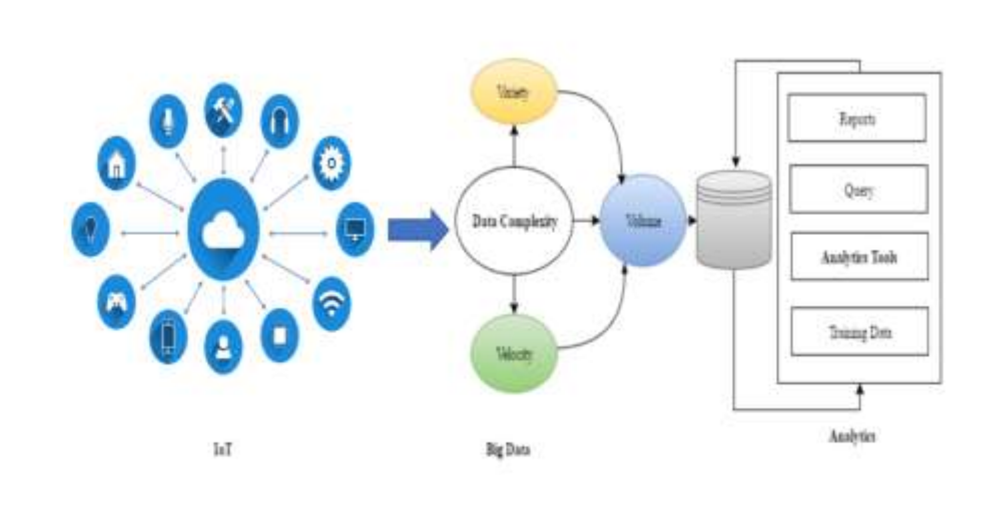

Figure6: Relationship between IoT and big data analytics

Contribution of Artificial intelligence (AI) along with machine learning to IoT be a key to unlocking the value of big data. In general, big data is currently hard to organize and analyses, thus data handling would become complex to store, retrieve and process. Under situations of large volumes of data, AI allows delegation of difficult pattern recognition, learning, and other tasks to computer-based approaches. Three different stages of AI have been evolved since it was coined at Dartmouth in 1956 [27]. In the 2010s, a new technology called deep learning (machine learning) was thrust into the limelight, and the third AI boom began. Deep learning is the latest artificial neural network technology, which simulates the mechanisms of the human brain. AI concept has been successfully implemented and tested by many companies including Facebook, Microsoft, Google and Tesla where the AI perform machine to machine learning, solving complex problems, powerful predictive capabilities autonomously-powered self-driving vehicles operations.

Apple Inc. product Siri takes one step ahead by saving human lives by making emergency phone and navigating the ferry to nearest shore [28]. Hence AI is strongly believed to enhance and accelerate the big data handling in IoT by performing specific problem-solving operation includes data-based decision making. Ultimately, IoT enterprises will use big data because it creates value by solving new problems, as well as solving existing problems faster or cheaper, or providing a better and richer understanding of those problems. As a result, a key role of machine learning and AI is to help create value by providing enterprises with intelligent analysis of that data and capturing structured interpretations of the wide variety of unstructured data increasingly available [29] as shown in Figure 7

Figure7: IoT can benefit from AI across most of its workflows

Machine learning is a sub field of computer science, a type of Artificial Intelligence, (AI), that provides machines with the ability to learn without explicit programming. Machine learning evolved from pattern recognition and Computational Learning Theory. There, some essential concepts of machine learning are discussed as well as, the frequently applied machine learning algorithms for smart data analysis [30]. The frequently applied machine learning algorithms to the IoT use cases are tabulated in Table 1

Machine learning Algorithm	IoT, Smart City use cases	Metric to Optimize
Classification	Smart Traffic	Traffic Prediction, Increase Data Abbreviation
Clustering	Smart Traffic, Smart Health	Traffic Prediction, Increase Data Abbreviation
Anomaly Detection	Smart Traffic, Smart Environment	Traffic Prediction, Increase Data Abbreviation, Finding Anomalies in Power Dataset
Support Vector Regression	Smart Weather Prediction	Forecasting
Linear Regression	Economics, Market analysis, Energy usage	Real Time Prediction, Reducing Amount of Data
Classification and Regression Trees	Smart Citizens	Real Time Prediction, Passengers Travel Pattern
Support Vector Machine	All Use Cases	Classify Data, Real Time Prediction
K-Nearest Neighbours	Smart Citizen	Passengers' Travel Pattern, Efficiency of the Learned Metric
Naive Bayes	Smart Agriculture, Smart Citizen	Food Safety, Passengers Travel Pattern, Estimate the Numbers of Nodes
K-Means	Smart City, Smart Home, Smart Citizen, Controlling Air and Traffic	Outlier Detection, fraud detection, Analyse Small Data set, Forecasting Energy Consumption, Passengers Travel Pattern, Stream Data Analyse
Density-Based Clustering	Smart Citizen	Labelling Data, Fraud Detection, Passengers Travel Pattern
Feed Forward Neural Network	Smart Health	Reducing Energy Consumption, Forecast the States of Elements, Overcome the Redundant Data and Information
Principal Component Analysis	Monitoring Public Places	Fault Detection

Canonical Correlation Analysis	Monitoring Public Places	Fault Detection
One-class Support Vector Machines	Smart Human Activity Control	Fraud Detection, Emerging Anomalies in the data

Table 1: Overview of applying machine learning algorithm to the IoT use cases. [30]

IV. AI AND IoT ENABLED CIRCULAR ECONOMY

The convergence of these technologies will generate extraordinary value-creation opportunities. AI and IoT enable circular economy give rise to a "factory of the future" model in which costs plummet; efficiency increases; and high-quality, quick-turnaround "batches of one" become feasible. In this line, emerging technologies such as 3D printing, Advanced Robotics, Wearables and Augmented Reality (AR) based construction, food, manufacturing, recreation industries will transform techniques of supply chain, logistic and asset management using AI and IoT concept. For example, asset management in an impending issue in circular economy as the result of poor infrastructure, insufficient knowledge about product re-usability, LE manufacturing practices.

By connecting the dots and efficient asset management in CE is possible using IoT concept by embedding a low-cost sensors in re-usable products/devices. Enabling IoT in CE will add the implementation cost, however IoT enable CE process that has the potential to produce little to no waste and is capable of recycling materials.

The nexus between the value drivers of the circular economy and the Internet of Things greatly enhances the circular economy. If an institution's goals are profitability and conservation, IoT enables those goals with big data analysis and Artificial intelligence. By automatically and remotely monitoring the efficiency during the manufacturing process and at the end of its use cycle, all parts of the value chain can become more efficient.

IoT using low cost RFID / QR sensors can aid in the asset retrieval during end of the product life cycle, so that it can be recycled into its components. With efficient reverse logistics, goods gain second life, suitable product recycling process with limited resource lost will accelerate CE concept worldwide [35]. IoT enabled leasing model transforms the traditional value chain into CE model. Instead of selling an expensive appliance or a vehicle, manufacturers willingly can produce them with the intention of leasing to their customers. By embedding these assets with IoT, manufacturers can monitor the asset's condition; thereby dynamically repairing the assets at precise times. In theory, the quality of the asset will improve, as it's in the producer's best interest to make it durable rather than disposable and replaceable

The opportunities presented by digital transformation and big data to support circular economy business models should not be underestimated as shown in Figure8. For example, product-as-a-service models and the sharing economy can result in dematerialization that has already had significant impacts on sustainability performance for many industries.

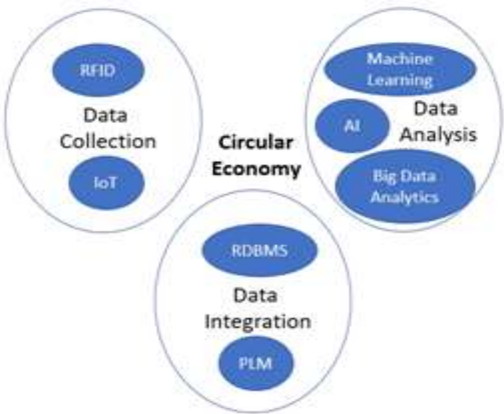

Figure8: The transformation of any physical object into a digital data product

The product life cycle is to be monitored to determine the number of reusable products. As optimization is struck by obtaining the potential reusable products / components through predictive analysis from big data. if the reusability is very less, then design for circular economy has no role in it. Alternatively, if there is a significant potential for regeneration orreusability, the design for circular economy strategy is to be obtained to minimize the waste and maximize the benefits. Thus IoT / Blockchain / AI / Big data are put into the environment for efficient monitoring and control of system.

V. CONCLUSION

Implementing circular economy is a complex activity. This requires behavioral change, on top of legislation. Emerging digital and smart data technologies IoT / Blockchain / AI / Big data such as provide an opportunity to overcome this challenge and means to evaluate implementation of producer responsibility laws.

The massive data generated during the manufacturing, use and disposal fits the characteristics of Big Data. They can be analyzed by applying big data business analytics and artificial intelligence (AI) to spot the trends and optimize the logistics and asset management in circular economy with help of IoT. Privacy of data is another reason for current IoT development and requires further innovations in blockchain and quantum encryption technologies. Wireless sensor networks integrated with internet of things (IoT) and cloud computing will provide new means to monitor, regulate, and enforce rules on the movement of circular economy

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