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Deploying Artificial Intelligence for Circular Economy and its Link with Sustainable Development Goals

Abhiraj Singh Rathore[1] and Paarul Malawalia[2]

[1] *B.Tech, Computer Science, Delhi Technological University, India*

[2] *B.A Hons, Political Science, Kamala Nehru College, University of Delhi, India*

Abstract

This paper explores three alternative concepts- Circular economy (CE), Sustainable development, and Artificial intelligence (AI) and outlines some of the key features that each one poses. In addition to that, the focus will be on the link between the three concepts and how each one of them facilitates the other. Transforming linear business models to circular economies globally is more important than ever. This is to sustain the rate of production and consumption to meet the ever-increasing consumer demand that is overloading the environment and society (here comes the concept of sustainable development). Adopting CE practices is an initial step towards achieving a sizable number of SDG targets. There is a clear correlation between the targets of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land).

In this context, Digital technologies are seen as the driving force for attaining the goal. Further, the paper explores the potentials of Artificial intelligence in the transition to a circular economy. It includes machine learning, deep learning which further have algorithms like classification algorithms (SVMs, neural networks), clustering, computer vision, object detection, NLP, etc. This paper offers an insight into the economic, social, technological, and environmental factors through an in-depth pestle analysis.

Keywords: *Circular economy, Linear economy, Sustainable development goals, Artificial intelligence*

1.0 Introduction

Industries all over the world have begun to consider the issue of sustainable development cautiously. The economy of a state marks its influence in the global village, it's based on how well run the nation-state is, with the least amount of waste and losses. The economic model followed by several states in the past few decades was the linear model of the economy, in which the use of raw materials is centralized. With the linear model, we can say that downcycling is the norm. Once the product has had its first life, it is destined to become trash. This means that the value of a product rapidly plummets from brand new to the price that an ironmonger would give for it.

This model is everything but sustainable and if this model continues to be the norm for economic models any longer, we will experience a depletion of many important raw materials before 2050.

In other words, action needs to be taken. We need to switch to an economic model in which recycling and reusing are central. This is where a circular economy comes into play. (Meulenyzer, 2020) A circular economy is a present-day strategy that is now gaining worldwide attention to conceptualize the integration of economic activity and environmental wellbeing sustainably. A circular economy model aims to close the gap between the production and the natural ecosystems' cycles – on which humans ultimately depend upon. This means, on one hand, eliminating waste – composting biodegradable waste or, if it's a transformed and non-biodegradable waste, reusing, remanufacturing, and finally recycling it. On the other hand, it also means cutting off the use of chemical substances (a way to help regenerate natural systems) and betting on renewable energy. (Circular Economy: Definition, Principles, Benefits and Barriers, 2020) In contrast to the linear economy, a circular economy is fundamentally different and is seen as a safer and more economical way to increase the efficiency of sustainable development through the reduction and recirculation of natural resources. This concept has the eyes of governments, scholars, companies, and citizens as a necessary step to achieve sustainable development. The world's population is growing at a fast pace and has the potential of affecting the environment adversely. The United Nations have suggested several "Sustainable Development Goals" (SDGs), to facilitate economic development, without depletion of earth's resources. SDGs have been described as "the blueprint to achieve a better and more sustainable future for all" by 2030. The seventeen goals and associated 169 targets are increasingly being adopted by both public and private sector actors across the globe, as a framework for organizing and pursuing sustainability initiatives. While the overall aim of CE and SDGs appear roughly the same (interpreted here as social and economic prosperity within the natural capacity of our planet), the linkages between these two agendas are not immediately obvious. The term 'circular economy' does not even occur once in the 2030 Agenda for Sustainable Development, where the SDGs and associated targets are set forth. (Einarsson, 2019)

This paper also highlights how artificial intelligence or AI can help nation-states to adopt and make efficient use of the circular economy. Artificial intelligence is a cluster of technologies and basically, a branch of computer science which deals with building models and machines that perform functions just as a human does like learning, and requires human intelligence. Artificial intelligence has the capability of understanding and learning from experience, unlike other software programs which are predetermined. In today's world, artificial intelligence has become one of the most prominent tools for data handling. It provides humankind with a whole different and reliable method to collect and integrate data, analyze the information, and use the results to improve decision making and also give predictive models. In this paper, we try to answer how AI is gradually becoming the solution to the world's most important challenges. Combining the two global trends; artificial intelligence and circular economy can not only accelerate the shift towards a sustainable future but can also minimize the negative environmental and social impacts. The paper uses PESTLE analysis for the same to show that we can move towards a more sustainable future.

2.0 The Acute Need for Circular Economy

To state the obvious, our approach towards the environment and its resources needs a new direction, to make them more sustainable. Having a circular economy facilitates that change. The circulatory system and the linear system differ from each other in the way in which value is created or maintained. A linear economy traditionally follows the "take-make-dispose" step-by-step plan. This means that raw materials are collected, then transformed into products that are used until they are finally discarded as waste. Value is created in this economic system by producing and selling as many products as possible. A circular economy follows the 3R approach: reduce, reuse, and recycle. Resource use is minimized (reduce). Reuse of products and parts is maximized (reuse). And finally, raw materials are reused (recycled) to a high standard. This can be done by using goods with more people, such as shared cars. Products can also be converted into services, such as Spotify sells listening licenses instead of CDs. This leads to Upcycling of wastes or no nonrecyclable wastes. Figure 1.0 depicts the same (Ministerie van Infrastructuur en Waterstaat, 2019a).

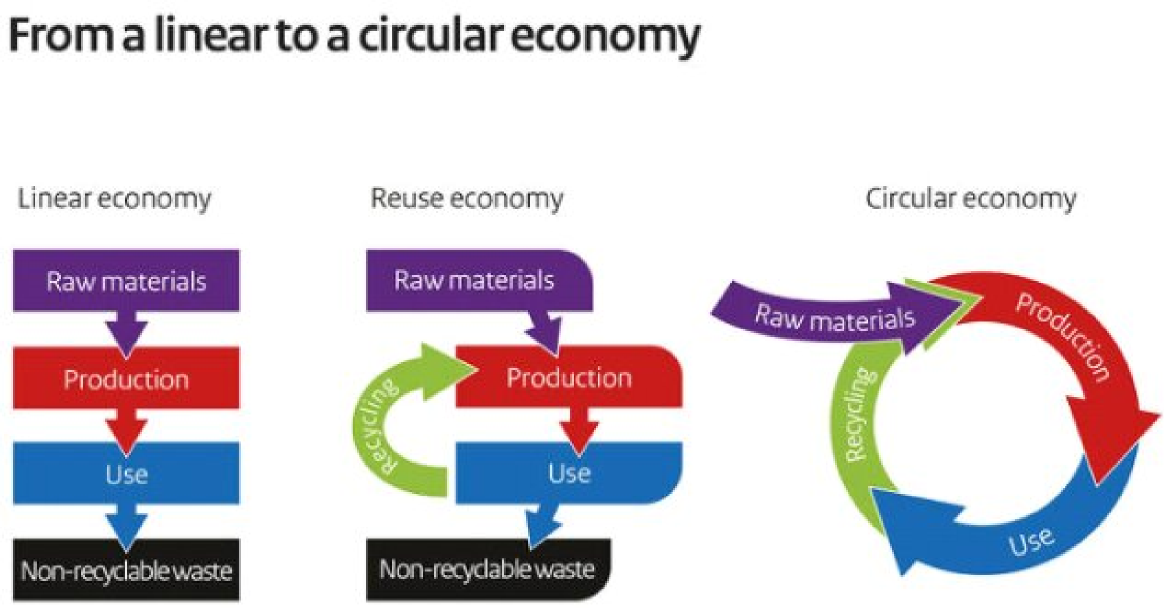

Figure 1.0 Different types of economic models

In the system of circular economy, value is created by focusing on value preservation and upcycling. The global population is fast growing and is expected to top 5 billion by 2030 and 10 billion in 2050. Naturally, there will be an increased demand for propensity and enormous stress on our resources which are not limitless.

For instance, globally, clothing production doubled between 2000 and 2015. During the period, the number of garments purchased each year increased by 60 per cent but the average number of times a garment was worn before disposal declined by 36 per cent. More than $500 billion worth of natural resources are lost every year due to clothing underutilization and the lack of recycling, says the report. Global bodies like the Organisation for Economic Co-operation and Development, the World Economic Forum (WEF), and the United Nations Environment Programme (UNEP) are also promoting circular economy through various events.

In 2017, WEF and its partners established the Platform for Accelerating the Circular Economy, or PACE, to drive action towards a circular economy. Under PACE, over 50 business and government leaders have come together to create favourable conditions for widespread adoption of the concept.

However, UNEP urges global leaders and think tanks to expand the scope of the circular economy beyond just recycling products. (DownToEarth. (2019, June). This is an all-encompassing approach to life and business, where everything has value and nothing is misspent. It can be explained as 'make, use, remake' as opposed to 'make, use, dispose of'.

The first advantage of a circular economy is the protection of the environment, reducing waste and the emissions of greenhouse gases, systematizing recycling, and ending planned obsolescence. The circular economy also allows decreasing the dependence on the importation of resources. (Solar Impulse Foundation, n.d.) CE opens an opportunity for businesses. By getting the maximum value out of the resources they use, they will gain the competitive benefits of forming longer-lasting relationships with customers, based on the provision of products and services rather than the sale of products alone.

People's quality of life can be improved worldwide through employment opportunities. Jobs based on service models could create jobs, many in higher-paid roles, and are likely to be locally based. It stimulates innovation and boosts economic growth, and could in the long run enhance the competitiveness of national companies. (Solar Impulse Foundation, n.d.)

Many countries currently import raw materials. For example, The Netherlands imports a lot of magnesium from China. In a circular economy, the Netherlands will be much less dependent on other countries. Products that used to be discarded and incinerated will be used as a source of raw materials in the future (Ministerie van Infrastructuur en Waterstaat, 2019).

3.0 Targets of the Circular Economic Model

A circular economy has very clear targets with the core intention of designing out waste:

- Energy and resources are gold- A circular economy is based on the idea that there is no such thing as waste. To achieve this, products are designed to last (good quality materials are used) and optimized for a cycle of disassembly and reuse that will make it easier to handle and transform or renew them. In the end, these tight product cycles differentiate the circular economy model apart from disposal and recycling, where large amounts of embedded energy and labour are lost. The ultimate goal is to preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows.

• Following Nature's Cycles and Designs- The circular economy model makes a distinction between technical and biological cycles. Consumption happens only in biological cycles, where biologically based materials are designed to feedback into the system through processes like anaerobic digestion and composting. These cycles regenerate living systems, such as soil or the oceans, which provide renewable resources for the economy. By their turn, technical cycles recover and restore products, components, and materials through strategies like reuse, repair, or recycling.

Ultimately, one of the purposes of the circular economy is to optimize resource yields by circulating products, components, and the materials in use at the highest utility at all times in both technical and biological cycles.

• All In With Renewable Energies- The last principle of a circular economy has to do with the fact that the energy required to fuel this cycle should be renewable by nature, to decrease resource dependence and increase systems resilience. In this sense, this principle is about developing the systems' effectiveness by revealing and designing out negative externalities. (Circular Economy: Definition, Principles, Benefits And Barriers, 2020)

4.0 Impacts and Benefits of the Circular Economic Model

The linear model of consumption and production has been used by humans for a long time now. Goods made from raw materials are consumed, sold, and later turned into waste and thrown away without any management. On the opposite, the circular economy is an industrial model that is regenerative by intention and design and aims to improve resources' performance and fight the volatility that climate change might bring to businesses. It has benefits that are operational as well as strategic and brings together a huge potential for value creation within the economical, business, environmental and societal spheres.

The circular economy has the potential to reduce greenhouse gas emissions and the use of raw materials, optimize agricultural productivity and decrease the negative externalities brought by the linear model.

Environmental Benefits:

a. **Reduced greenhouse gas emissions** - One of the goals of the circular economy is to have a positive effect on the planet's ecosystems and to fight the excessive exploitation of natural resources. When it comes to reducing greenhouse gases, a circular economy can be helpful: Because it uses renewable energy that in the long run is less polluting than fossil fuels. Thanks to reusing and dematerializing, fewer materials and production processes are needed to provide good and functional products. Because residues are seen as valuable and they are absorbed as much as possible to be reused in the process. Since the preferred choices will be energy-efficient and non-toxic materials and manufacturing and recycling processes will be selected. An Ellen MacArthur Foundation study found out that a circular economy development path could halve carbon dioxide emissions by 2030, relative to 2018 levels (you matter, 2020).

   By following the principles of the circular economy, greenhouse gas emissions are automatically reduced on a global scale. Climate change and the use of materials are closely linked. According to Circle Economy calculations, 62% of global greenhouse gas emissions (excluding those from land use and forestry) come from the extraction, processing, and production of goods to meet society's needs; only 38% are emitted in the supply and use of products and services. For example, emissions from industry in the European Union would fall by 56% in 2050 if the circular economy were to become a reality. The reduction in emissions measured on a global scale will be even greater because the European Union will no longer import primary raw materials from countries outside the Union, which will also reduce greenhouse gas emissions in those countries (What Are the Environmental Benefits of the Circular Economy? n.d.).

b. **Healthy and resilient soils, vital air and water bodies** - The application of circularity in the economy creates vital ecosystems such as soil, air, and water bodies. These ecosystems provide services such as cleaning, products such as fertile farmland, pollination, and clean drinking water. In a linear economy, these services are ultimately depleted by constant withdrawal of products or overburdened by the dumping of toxins. If these products are used in a cycle and the services are not burdened by toxic substances, the soil, air, and water bodies remain resilient and productive (What Are the

Environmental Benefits of the Circular Economy? n.d.) The principles of the circular economy on the farming system ensure that important nutrients are returned to the soil through anaerobic processes or composting, which softens the exploitation of land and natural ecosystems. In this way, as "waste" is returned to the soil, besides having fewer residues to deal with, the soil gets healthier and more resilient, allowing a greater balance in the ecosystems that surround it. As well, since soil degradation costs an estimated US$40 billion annually worldwide, and has hidden costs such as the increase of fertilizer use, loss of biodiversity, and loss of unique landscapes – a circular economy could prove to be useful for both the soils and the economy. In reality, a circular economy model working in Europe's food systems has the potential to decrease 80% of the use of artificial fertilizer and therefore contributing to the natural balance of soils, according to a study from the Ellen MacArthur Foundation (you matter, 2020).

c. **Conservation of nature reserves** - The extraction of raw materials and the dumping of waste harm nature reserves. These natural areas are important for the preservation of ecosystem services, natural and cultural heritage. At the moment, many governments and organizations are mainly involved in protecting nature from extraction and the dumping of raw materials and waste. To systematically preserve nature, this extraction and dumping must stop in general. This is achieved within the circular economy (What Are the Environmental Benefits of the Circular Economy? n.d.).

Economic Benefits:

a. **Increased Potential For Economic Growth** - An important principle of a circular economy is to decouple economic growth from the consumption of raw materials. As a result, the economy is not hampered by the shortage of raw materials to grow. It is assumed that a move towards the circular economy will promote economic growth. The United Nations Environmental Plan (UNEP) calculated that in 2050 the global economy would benefit from more effective resource use by $2 trillion a year. In a circular economy, this gain would certainly be achieved. On the one hand through increased turnover from new circular activities and on the other hand through the creation of more functionality from the same number of materials and means of production.

The development, production, and maintenance of these circular products require a specialized workforce, which will increase these jobs. On the other hand, there will be less demand for the extraction and processing of raw materials, which will reduce the number of less specialized jobs. This will increase the value of labour, which is good for employment and GNP (What are the economic benefits of the circular economy? - Kenniskaarten - het Groene Brein, n.d.).

b. **More Resources Saved** - When compared with the raw material extraction that's common on the linear approach, the circular economy model has the potential to lead to a bigger (up to 70%) (Towards the Circular Economy: Accelerating the Scale-up across Global Supply Chains, 2014) amount of material savings. Considering that the total demand for materials will increase due to the growth of the world population and middle classes, a circular economy leads to lower material needs, as it skips landfills and avoids recycling, focusing on making materials' cycles last longer. On the environmental side, it also avoids bigger pollution that extracting new materials would represent (you matter, 2020).

c. **Employment Growth** - According to the 'world economic forum' (An Economic Opportunity Worth BillionsâCharting the New Territory, n.d.), the development of a circular economy model, together with a new regulation (including taxation) and organization of the labour markets, can bring greater local employment in entry-level and semi-skilled jobs. A conclusion was reached by an August 2018 study (Kalmykova et al., 2018, p. 197) on the development of practices to implement a circular economy that said that 50,000 new jobs could be generated in the UK and 54,000 in the Netherlands. Another study (DELIVERING THE CIRCULAR ECONOMY A TOOLKIT FOR POLICYMAKERS, 2015)conducted by the Ellen MacArthur Foundation and McKinsey also concluded on the changes in employment growth in case of a shift to a circular economy model. The study says that these new jobs will be created through increases in:
Recycling and repairing practices, where one could add new designers and mechanical engineers to make lasting and easily disassembled products and materials at the transformation/production stages; an increase in new businesses (and niches) due to innovation processes and new business models; an increase in consumption and spending

by lower prices. (you matter, 2020)

d. **Changing demand** - A final important factor in the economic benefits of a circular economy is the change in and better understanding of the demand side. How companies deal with their customers and the role they play throughout their lives ultimately leads to less use of raw materials, less waste generation, and changing production (Towards the Circular Economy: Accelerating the Scale-up across Global Supply Chains, 2014) (What Are the Environmental Benefits of the Circular Economy? n.d.).

Benefits On Businesses:

a. **New Profit Opportunities** - Lower input costs and in some cases create entirely new profit streams that can be achieved by businesses that move to the circular economy model. In this circular sphere, profit opportunities may come from playing in new markets, cutting costs off with waste and energy reductions, and the assurance of continuity of supply (you matter, 2020).
b. **Volatility Reduction And Safeguarded Supplies** - Moving towards a circular economy model means reducing the number of raw materials used. Instead, more recycled (or even reusable or easily transformed) inputs that have a higher share of labour costs would be used, leaving companies less dependent on the volatility of the price of raw materials. This would also protect companies from geopolitical crises and safeguard them regarding their supply chains – whose probably to be destroyed or damaged because of climate change events is increasing every day. In the end, the circular economy model would turn businesses more resilient, or in other words, make them more resistant and prepared to deal with unexpected changes (you matter, 2020).
c. **The Demand For New Services** - According to Ellen McArthur's Foundation report (TOWARDS A CIRCULAR ECONOMY: BUSINESS RATIONALE FOR AN ACCELERATED TRANSITION, 2015), a circular economy model has the potential to create demand for new services and new job opportunities such as:

   I. Collection and reverse logistics companies that support the end of life products being reintroduced into the system.

II. Product marketers and sales platforms that facilitate longer lives or higher utilization of products.

III. Parts and component remanufacturing and product refurbishment offering specialized knowledge.

These new services can be both identified by the top management decision-makers, or as well, in a well-developed green by employees from all levels and departments (you matter, 2020).

5.0 Towards Sustainable Development through the Circular Economy

In this section, we try to identify the extent to which circular economy practices are admissible to the implementation of Sustainable development goals. A recent study published in the Journal of Industrial Ecology sheds some light on the possible interlinkages between the CE and the SDGs. The study, which is based on a broad literature review, explores the extent to which CE practices are relevant for implementing the SDGs in a developing country context. 'CE practices' as defined in the study, comprise a broad range of practices and business models such as reuse, repair, refurbishment, remanufacturing, recycling, industrial symbiosis, biomimicry, product sharing, and supporting design practices. The study concludes that "CE practices can be applied as a 'toolbox' and specific implementation approaches for achieving a sizable number of SDG targets" and thus highlights the importance of the CE transition for successfully achieving the SDGs. (What Is the Link between Circular Economy (CE) and the Sustainable Development Goals (SDGs)? n.d.)

SDGs strongly and directly benefiting from CE practices:

According to the study, establishing CE practices can positively contribute to achieving 21 SDG targets. The strongest relationship that directly connects CE and SDGs are related to:

SDG 6 – Clean Water and Sanitation: CE practices such as small-scale water purification, sustainable sanitization, wastewater treatment, water reuse and recycling, nutrient recovery, biogas systems, etc. can help improve access to safe drinking water and equitable sanitation, reduce pollution and improve water quality.

SDG 7 – Affordable and Clean Energy: Renewable energy systems, including small-scale biomass technologies and 2nd generation biofuels, energy (heat) recovery and improved utilization in industrial systems (e.g. industrial symbiosis) all contribute to this goal.

SDG 8 – Decent Work and Economic Growth: New circular business models are a major potential source of increased resource effectiveness and efficiency, waste valorization, and green jobs. Economic growth should be an exaggerating force for the whole planet.

SDG 12 – Sustainable Consumption and Production: CE practices are all about dissociating economic activity from resource use and associated environmental and social impacts, which is also very much at the heart of this goal. This goal is an important enabler for achieving most of the other SDGs, making the indirect impact of CE practices even more profound.

SDG 15 – Life on Land: The goal of restoring natural capital is at the heart of CE procedures. This entails implementing sustainable and regenerative agriculture and agroforestry practices that value and protect biodiversity while also returning biological material to soils as nutrients – practices that are critical for the restoration of terrestrial ecosystems.

SDGs indirectly benefiting from CE practice:

On top of contributing directly, CE practices can also contribute indirectly to various SDGs, via some of the more directly affected goals – thus contributing positively to additional 28 targets. The strongest indirect relationships are related to:

SDG 1 – No Poverty: Adoption of CE practices, such as repair, remanufacturing, and recycling can give rise to employment opportunities, which indirectly contributes to poverty reduction. CE practices, like water management and agriculture, also build resilience.

SDG 2 – Zero Hunger: Implementing CE principles in local agriculture, e.g. composting and diversified integrated farming practices, improves soil quality which further increases farm productivity and system resilience. Merging with circular food system initiatives that reduce food waste and/or cascading of food waste into animal feed can free up farm-land for human consumption.

SDG 11 – Sustainable Cities and Communities: There's an expectation that almost three-quarters of the world's population will live in cities in 2050, therefore a transition to a circular economy is imperative for reducing cities' resource and environmental impacts. CE practices such as modular, adaptable, and flexible building design, can help enable access to housing for low-income groups.

SDG 14 – Life below Water: To prevent waste from entering the oceans, waste generation and leakages from land-based activities can be reduced through CE practices. This also includes the restoration of nutrients from wastewater streams before entering oceans. Besides, CE's contribution to tackling climate change will indirectly reduce ocean acidification.

SDGs facilitating the uptake of CE practices:

Several SDGs, including 52 targets, will "positively contribute to the uptake of CE worldwide," according to the study. These factors can be viewed as some of the key enablers of the CE transition. They are as follows:

SDG 4 – Quality Education: Efforts to achieve several of the targets related to, for example, equal access to technical, vocational, and tertiary education – particularly when combined with a focus on CE, systems thinking, design for circularity, entrepreneurship, and innovation – are crucial for allowing circular practices.

SDG 9 – Industry, Innovation, and Infrastructure: While CE practices would directly contribute to retrofitting industries to make them more resilient and sustainable, meeting the goals outlined in this goal is also crucial to enabling a CE. New infrastructure for renewable energy, circular water, waste/resource management, reverse logistics, support for research and innovation, and ensuring access to appropriate funding are all part of this.

SDG 10 – Reduced Inequalities: Promoting safe working conditions has strong synergies with social and economic inclusion, which is especially important for workers in the informal waste sector in developing countries. This goal is also tied to ensuring that developing countries have equal representation in international cooperation, equal access to technical assistance and funding for a CE and those trade agreements promote rather than hinder development.

SDG 13 – Climate Action: CE practices have both impacts on climate change mitigation and resilience. In addition to the regular low-carbon technologies, the 2019 Circular Gap Report finds that introducing CE practices could reduce GHG emissions by more than a third by 2100. Additionally, achieving climate-related policy targets at the national, regional, and local levels, as well as incentives, funding mechanisms, and increased climate awareness, are likely to promote the adoption of CE practices

SDG 16 – Peace, Justice, and Strong Institutions: Environmental justice is benefited by CE practices since improved and more equitable access to basic resources, as well as increased natural system resilience, contribute to environmental justice and can help indirectly prevent environmentally triggered social conflicts. Additionally, meeting the goals outlined in this goal - stronger institutions, reduced corruption, and increased transparency - will aid in the implementation of CE procedures, such as in the creation of new jobs.

SDG 17 – Partnership for the Goals: According to the study, meeting targets for debt relief for developing countries, more equitable free trade systems and agreements, enhanced macroeconomic stability, improved global sustainability policy, and developing countries' access to technical assistance can all help CE practices.

6.0 Artificial Intelligence in the Transition to Circular Economy

6.1 What is AI?

Artificial Intelligence (AI) is one of the key drivers of the Fourth Industrial Revolution. It can be loosely defined as software mimicking aspects of human behaviour. Amongst others, this includes learning, reasoning, problem-solving, knowledge representation, perception, motion, social intelligence, and creativity. To a great extent, AI achieves this by employing algorithms that find patterns and extract useful information from (large amounts of) data. Thanks to recent computational advances, today we can meet the operational requirements to develop such software. There are a few approaches for mimicking human intelligence, and at the core of those is machine learning. Machine learning methods, unlike conventional algorithms, are dynamic and can adjust in response to the data to which they are exposed and hence applicable to many domains.

Machine learning is a broad field, but algorithms are often grouped into three main categories:

1. Supervised learning
2. Unsupervised learning
3. Reinforcement learning

In supervised learning, the algorithm learns by exploiting the ground truth. That is, input datasets are associated with a known outcome and the algorithm learns by example, the importance attributed to each input to correctly predict the outcome. On the other hand, for unsupervised methods, the goal is to automatically discover the inherited structure of the data without any prior knowledge. Often, the result is the creation of clusters that group data with similar properties together. Lastly, in reinforcement learning, the model learns based on a reward system, where it gets rewarded when making the right decisions, from a set of allowed actions under particular circumstances, and penalized when making wrong ones. Rather than knowing a ground truth, the system learns by itself courtesy of trying to maximize the number of reward points. Another important category is natural language processing (NLP). These methods generally fall under supervised learning but because they deal with the understanding and usage of language by computers, they are often referred to separately. NLP is further subdivided into two other categories, Natural Language Understanding (NLU) which deals with deriving human-understandable context/meaning from digital text, and Natural Language Generation (NLG) which deal with text composition into a humanly understandable form. Depending on the desired outcome algorithms that comprise the above categories are used to train models to perform the necessary functionality. In real-world applications, more than one AI model is developed to carry out the expected functionality. The skilled developer can recognize which of the algorithms can be used, and interfaced appropriately, to create such solutions (Leveraging Artificial Intelligence to Advance Circular Economy, 2020)

6.2 How exactly does AI work?

There is a common misconception that AI algorithms are 'smart' by themselves. AI is dependent on humans to establish the inputs and outputs for a model (a piece of software) before a machine can solve it.

An example is the voice assistant such as Siri, Alexa, or Google Assistant - which needs to be able to understand speech and respond with a sensible answer or action. However, to effectively train the algorithm and adjust the input data accordingly, humans need to know what type of questions they expect to be asked and what a sensible response would be. The lifecycle of AI development typically follows a process of data collection and 'engineering', algorithm development using the engineered data, and refinement as the data input is tweaked to achieve the expected outcome. Once the expected outcomes have been achieved to an acceptable level, decisions can be made based on the output of the algorithm. As the quality of the data improves over time, the quality of the output of the algorithm will also increase.

Take the simple example of developing an AI algorithm that can recognize pictures of cats. The right kind of data has to be collected (in this case photos of cats and other animals) and it has to be 'engineered' - that is, reformatted and labelled so the algorithm can understand what it is looking at. The photos with cats and other animals will have to be tagged as 'cat' or 'not cat' so the algorithm can learn what type of features are unique to a cat. The data engineering process often requires a lot of manual work to manipulate the data into the right format. What you put in is what you get out, so good quality data is a very important consideration for applications of AI. The algorithm is trained using the labelled photos of cats and other animals and refined until it can apply what it has learned to unknown photos. Humans need to know what they expect to see as a result of the algorithm performing its task so the results can be sense-checked. The results, for example, may include both photos of cats and photos of cat toys. The algorithm will then be refined to recognize the difference between a real or fake cat using additional images and information. Each algorithm is trained to perform a very specific function, such as object detection for autonomous driving, identifying fraudulent financial transactions, or delivery route optimization (Artificial Intelligence and the Circular Economy, n.d.)

6.3 How can AI advance the Circular Economy?

The transition towards a circular economy may be one of the biggest opportunities for the global economy as a whole. AI has a large role to play, and the various AI applications can help unlock a value of 127 billion USD per year by 2030 in food alone. Attributing the company's digitization efforts to focus towards CE goals is essential. For example, on the business and product development side, products that are a result of both technological and circular principles enhance innovation and can create significant economic opportunities. AI is a broad term covering many principles and technologies. We will now introduce algorithms that can be developed and applied in Circular Economics across various industries.

In many cases, a ‘mix-and-match approach can address potential needs.

1. Clustering: A single data entry can be described using many quantifiable attributes. In technical terms, we call the number of attributes features or dimensions. For example, in geographical terms, a city can be uniquely described using two attributes, longitude and latitude. Colours can be described with three attributes, their relative composition of red, green, and blue. Clustering algorithms take as input the features/attributes and aim to create groups of the various data points. The applicability of clustering algorithms can be found when creating digital sharing platforms. Relative distances between those that own specialized equipment and those that want to use it can be quantified in this manner and help bring stakeholders together. For example, shared platforms can be used by local authorities using shared resources or by hardware companies renting out equipment.

2. Time Series Analysis: Time Series describes how a variable evolves. For example, resource consumption in a building can be described as the amount of water spent during the day. Time Series analysis can be used to detect any repeating patterns or to predict future events. Methods include Fourier transforms, spectrograms, lines of best fit and extrapolation, and even deep learning models like Long Short-Term Memory (LSTM). Applications can be found in the preventative maintenance of electronic equipment by monitoring device health, urban resource monitoring such as water, and even efficient food production where consumption can be monitored to predict future demand.

3. Outlier detection: For equipment, operability occurs within a certain set of values. For humans, a healthy state is usually inferred by comparing metrics such as heart rate or glucose to those that we know are considered normal. Outlier detection algorithms take in data values and define normality by looking at statistical measures such as mean, standard deviation, kurtosis (the sharpness of the peak of a frequency-distribution curve), and many more. This data-driven approach can define “normal operating conditions”', enabling algorithms to detect when values go beyond such range. Outlier detection is applicable in product maintenance, urban resource monitoring (e.g. average water

consumption of a given household), healthcare, and many more. In general, where numbers can be used to describe ranges, outlier detection can help in addressing deviation from normality.

4. Computer Vision, object detection (and classification): Image analysis is when algorithms are trained to detect whether a particular object is found within an image or not. Invariably image analysis is a classification problem, as the algorithms learn to classify whether an object is present in an image, and if applicable, wherein the image such an object is found. There exist many classification algorithms, each applicable under specific scenarios, examples including logistic regression, Support Vector Machines (SVMs), and (deep) Neural Networks (NN). Computer vision can be applicable in urban waste management (e.g. detecting when waste bins are full), healthcare (detecting bone fractures in X-rays), recycling (sorting objects into those that can be recycled or reused and those that cannot), and food production (detecting the color and size of a mature crop).

5. Chatbots: Chatbots, or more formally conversational agents, can be used to engage with humans. Ultimately chatbots can be used to understand what someone wants and reply to them accordingly with correct information. NLP algorithms are used to derive meaning from text. Various algorithms exist whose objective is to quantify words in a text to be able to compute, or derive, meaning from it. Chatbots can be used in education, where for example users can ask routine questions and receive replies that are consistent with company policy, or in healthcare for self-diagnosis and referral of non-urgent situations. Another application includes use in client contact, account management, etc.

6. Entity recognition: Entity recognition (ER), an NLU algorithm, takes as input a piece of digital text and produces as output structured data in the form of annotated entities found within the text. For example, in the sentence "John has been diagnosed with a mild headache and was prescribed paracetamol". Possible output is "Person: John, Name: John, diagnosis: headache, medicine: paracetamol". ER can be used in healthcare to

quickly create or review patient histories. ER is also useful in any industry that deals with parsing texts such as the regulatory or financial services industries.

7. Summarisation: Summarisation is also an NLU algorithm. Summarisation algorithms take as input large pieces of text and return a summary of the contained information. Approaches usually involve ascribing an important value to each word, for example via its frequency in a given text. Then each word's importance contributes to overall sentence importance, enabling the creation of summaries. Summarisation can be useful to any industry that deals with large bodies of text such as healthcare (e.g. patient history reports), education, and the governmental sector (e.g. large volumes of educational material converted to summaries).

8. Text classification with Natural Language Understanding: Natural Language Understanding: (NLU) algorithms convert words into quantifiable objects. Once in a quantitative format, the words can be processed with classification algorithms. One example, perhaps relevant to governmental authorities or the healthcare industry, is to classify text into various subjects/topics. This allows easy indexing of existing and new documents by processing the contents of the document with NLU methods. Another example, more relevant to the financial and regulatory industry, is to assess the risk of customers based on reports that gather data that describe their activity. Keywords such as money laundering, imprisonment, etc. can describe someone with a high-risk profile. NLU algorithms can be used to parse the text and automatically classify the risk of a potential customer (Leveraging Artificial Intelligence to Advance Circular Economy, 2020).

9. Creating regenerative systems by introducing AI to design, business models, and infrastructure: AI can be a hugely powerful tool. It can be used to accelerate the transition to a circular economy and create new opportunities for large-scale positive change. Employing AI in our design, business models, and infrastructure can increase our ability to create new, regenerative systems based on the principles of circularity.

10. Design powered by AI: The circular economy puts a strong focus on design. Indeed, the Circular Design Guide (The Circular Design Guide, n.d.) asks: what if you could redesign everything? Designers working with AI can create products, components, and materials that are fit for the circular economy. Employing AI can account for better designs faster, due to the speed with which an AI algorithm can analyze large amounts of data and suggest initial designs or design adjustments. A designer can then review, tweak, and approve adjustments based on that data. AI gives designers a more informed insight into the most effective designs to create and test to make the best use of their time and expertise. Three key benefits of AI in design:

- Cutting through complexity: Sifting through countless designs and suggesting the ones that best fit the circular design criteria.
- Speeding up the design process: Algorithms can rapidly analyze large quantities of well-labelled data, such as material databases and consumer preference data.
- Coming up with novel designs: AI can help humans think outside the box, remove bias, and design things in new ways.

11. Enabling new business models with AI: Since the industrial revolution, the linear economic system has become gradually more optimized and efficient, most recently using digital technologies such as AI. Similar techniques could be applied more widely to circular business models to increase their competitiveness.

    Ways in which AI could assist in creating circular business models:

- Dynamic Pricing such as lowering the price of food as it approaches its expiry date to reduce food waste.
- Matching algorithms for sharing or second-hand platforms to effectively connect people with the things they want, from tools to apartments.
- Predictive maintenance and prediction of reverse logistics demands.

12. Infrastructure: Streamlining the circulation of materials in the economy: Products at the end of their life are not as uniform as they were when first manufactured, so they are harder to automatically disassemble, sort, and separate. Their condition typically needs to be manually inspected and then treated based on what damage or wear and tear they have sustained. There are many opportunities for AI to help streamline the infrastructure needed to circulate materials in the economy - many of them focusing on the ability of AI algorithms to recognize and identify objects using cameras and other sensors.

    Ways in which AI can impact infrastructure:

- Automated assessment: Automated condition assessment of used products, and recommendations for whether they can be reused, resold, repaired, or recycled to maximize value preservation.
- Automated disassembly: Automated disassembly of used products employing AI to assess and adjust the disassembly equipment settings based on the condition and position of a product.
- Sorting: Sorting of post-consumer mixed material streams using AI visual recognition techniques combined with robotics (Artificial Intelligence and the Circular Economy, n.d.).

7.0 Analysis

Several factors can help grow or slow down the implementation of the circular economy model and are detailed with a PESTLE analysis. PESTLE is the acronym for political, economic, social, technological, legal, and environmental factors. It has been applied to the concept of circular economy to assess the factors having an impact on the development of this economy. Some of the beneficial factors can be perceived as drivers whereas others are detrimental to the development of a circular economy and appear as barriers.

Political factors:

Political forces influence not only transnational corporations' investment decisions, but also companies through the Circular Economy. The cost of doing business, as well as long-term viability, is influenced by the political climate and other factors. The majority of cases indicate that AI can pose a threat to democratic institutions. Data surveillance, privacy violations, and election hacking are only a few examples of these risks. But, AI is here to stay, whether users like it or not. Despite scepticism about AI's use, there is no doubt that it will aid in the consolidation of organisations, methods, cultures, and ideologies. If applied correctly, artificial intelligence has the potential to reduce administrative burdens.

Economic factors:

The transition between a linear model to a circular model requires important changes within a company. There is also the possibility that institutions can use Artificial Intelligence to predict supply and demand changes to mitigate or even prevent the impact of economic downturns. These changes that AI can bring about can take economics to greater heights. (Contributor, 2020). Moving from a linear to a circular model involves making the employees' mentality evolve. New designs, long-term strategy, and impacts for the products must be taken into account daily. There is a talk that it will become possible for businesses and organizations to implement AI techniques in understanding consumer behaviour and have it down to a science. The circular economy has been gaining traction with business and government leaders alike. If we transition to a circular economy, the impact will be felt across society. Some of the potential macroeconomic benefits of shifting to a circular economy are economic growth, material cost savings, job creation potential, and innovation (The Circular Economy In Detail, n.d.).

Social factors:

To face the demand of a growing population with limited resources, new consumption patterns must be found. (United Nations 2015). The linear model "make, take, waste" is so much fixed in customers' minds that it might be difficult to make them adopt a new way of consuming, for example by sharing items, or by buying second hand-products made from recycling. Sharing raw materials and supply streams, giving away or selling by-products, and providing used items can be synonymous with revealing key and confidential information for industrials on their stocks, production, and consumption (Comprehensive Analysis of the Existing and Emerging Approaches of Circular Economy Models in Pulp and Paper Industry, 2017).

Technological factors:

Innovative technology can help companies lead the transition to an inclusive, circular economy faster and more efficiently. AI provides a lot of time-saving and efficiency-related measures. With automation comes increased work output. (Contributor, 2020). Technological advancement has catalyzed the development and implementation of circular business models, driving new processes, new communication channels, and new operational efficiencies that enable the decoupling of resource use from economic growth across industries and on a global scale (These 5 Disruptive Technologies Are Driving the Circular Economy, 2017). Novel technologies provide the turnkey solution to decoupling economic growth and ecological degradation. New research fields are developing and will enable circular resource production-consumption patterns in a short timeframe.

Machine learning can Optimise production processes based on flows of demand. When coupled with the IoT technology, machine learning can enhance supply streams in eco-industrial parks and reduce energy consumption (Comprehensive Analysis of the Existing and Emerging Approaches of Circular Economy Models in Pulp and Paper Industry, 2017).

Environmental factors:

The potential benefits of shifting to a circular economy extend beyond the economy and into the natural environment. By designing out waste and pollution, keeping products and materials in use, and regenerating rather than degrading natural systems, the circular economy represents a powerful contribution to achieving global climate targets. It will reduce carbon dioxide emissions to a great extent. It will also result in the reduction of primary material consumption, increase land productivity and improve soil health. (The Circular Economy In Detail, n.d.) As the field of AI develops, so will the potential to protect the environment. From the land and air to both drinking and ocean water, AI is shaping up to be the key that governments, organizations, and individuals can tap to work toward a cleaner planet. (Creative, 2018)

Legal factors:

There are a few legal stumbling blocks in the way of a circular economy. Anyone can make the changes and start opportunities based on the circular economy, but the legal system can be an obstacle for many industries. The future of Artificial Intelligence in legal services is bright, and embracing it means a more efficient law firm able to streamline its service lines and give existing clients and potential clients what they need. It is, in general, productive.

8.0 Recommendations

Organizations can implement these strategies while developing solutions that help AI to accelerate the transition to Circular Economics:

1. Businesses can embed Circular Economic targets into their strategies and utilize the opportunity to use digital transformation to reach them.
2. Increased capital mobilization towards businesses developing and scaling AI for appropriate reasons will help to accelerate the transition to Circular Economics. These investment strategies can also help investors mitigate climate risk in their portfolios.
3. Governments can assist by implementing laws and policies to facilitate and accelerate the adoption of new technology and circular business models and this will help in scaling the restorative practices.
4. The ecosystem for innovation can be enhanced to increase public-private cooperation to reach national Circular Economy goals.

9.0 Conclusion

Women represent 80 per cent of those displaced by climate disruption; polluted water kills a further 1.8 million, predominantly children; and 1.3 billion people remain poor and some 700 million hungry. And for too long, we have been waging a senseless and suicidal war on nature. The result is three interlinked environmental crises", Secretary-General António Guterres told a virtual press briefing on the UN Environment Programme (UNEP) report, Making Peace with Nature. The only solution is to inherently follow the Sustainable development goals, to give back to nature, without losing economic efficiency. (United Nations, 2021).

Having a circular economy can effectively support the state to pursue Sustainable development goals and having an Artificial intelligence system to back up this process, can bring a positive change. If AI and CE practice is paired, they have the potential to transform the global economic system, benefiting businesses, individuals, and the environment. Every day, it becomes apparent that our current system, economic processes, and practices must change. In this paper, we were able to deduce the relevance of a circular economy in opposition to a linear model, due to its system of more reduction and recirculation of natural resources, in an economically and environmentally efficient manner. We were also able to review several reasons for which the efficient system of artificial intelligence can further facilitate better functioning of the circular economic model. Individuals have the democratic chance to voice out about the future they want, whether through voting, purchasing decisions, or conscious consumption. We can all speed up the transition to Circular Economic practices if we work together.

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