Chapter

Sustainability Route for Industry 4.0: The Future of Global Circular Economic Transition

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Abstract

The traditional linear models have proved to be ineffective in perspective of the limited resources of the earth and there is an intensifying stress on the resource side due to the ever-rising global population. Moreover, this results in the unsustainable and inefficient consumption of natural resources, increasing costs of commodities and volatility in the markets, which are unaffordable for the manufacturing base of our economy. The current business models based on the traditional economic policies are not only blindly followed globally but they also neglect the organizational specifics. The circular economy or closed-loop economy is an approach in which the waste or residuals from an industry can be used as raw material for another industry there by reducing the demand on earth's natural resources. The expected ultimate goal of this circular system is the reduction of gap between the organizational characteristics like profitability, organizational structure and decision making policies, market position and the adoption of circular economic practices.

Keywords: sustainability, Environment Management Systems, industry 4.0, economic development, circular economy, carrying capacity

1. Introduction

The idea is to dream about an economic model where the products that we use today are tomorrow's resources which results in creation of a cycle that encourages development in this world running by a limited amount of resources. Therefore, it is equally important to address some of the numerous challenges in the present scenario. Traditional linear paradigm (take-make-dispose) has proved to be inefficient in perspective of the finite resources of the earth and there is a mounting stress on the resource side due to the ever-rising global population. In addition, this results in the unsustainable and inefficient consumption of natural resources, increasing costs of commodities and volatility in the markets, which are unaffordable for the manufacturing base of our economy. As an imminent response to these upcoming challenges, we should adopt a circular economic model thereby shifting the current economic model of 'take-make-dispose' to designing products capable of regeneration which should also be accompanied by secondary benefits such as innovations and growth in employability of the economy. The time has come

to provide the deserving importance to the circular economy, which is the only plausible and deep-rooted solution to our present challenges and future endeavors.

As we all know, the future is Industry 4.0 which is considered globally as the fourth industrial revolution. The world as we know it is going through its imminent transformation from traditional business models to a digitalized era and it is imperative to us to discuss the impacts and outcomes of this transition towards the ecological and economical sustainability of the world as well as how the circular economic model will be adapting to this massive transformation. Industry 4.0 and the related digitalization of industries are undergoing an exponential progress. While an individual's life is reshaped by the tremendous advancement of industrial digitalization, the world is optimistically looking forward to its impact on Sustainability. According to the MICMAC analysis conducted by reveals that production efficiency and business model innovation which are the economic sustainability functions are the one to be impacted as an immediate outcome of Industry 4.0, which in turn leads its way to the advancement of socio-ecological sustainability functions of Industry 4.0 which are social welfare improvement, reduction of harmful emissions and energy sustainability [1]. This chapter provides a deeper understanding of what the digital industrialization can offer for sustainability and also measures to make sure that I4.0 delivers the expected sustainability functions globally effectively, equally and fairly.

2. Current Economic Paradigm: Linear Economy

Even though the current economic paradigm followed in a global scale underwent radical evolution and development over the years, the economy still sticks to the fundamental characteristic, which came to action during the initial stages of industrialization. The linear economic model which follows the cycle of 'take-make-dispose' has proved to be inefficient and not resource friendly in the long run. Industries source materials, implement labor force to manufacture the desired product and is sold to a customer- 'which in turn he discards after use' does not fulfill the purpose of sustainable development which is really hot topic required at a global scale. However, large-scale improvements are undertaken in the current model, any code, which does not concentrate on economic and restorative consumption of finite resources, will lead to imminent losses throughout the value string [2–5].

In the recent past, many companies started to surface the disadvantages and risks related with the linear economic model. The most notable risks is the surge of resource prices which tangles the businesses between the unchangeable demand expressed by consumer markets on one side and the mercurial and precarious market prices of raw materials on the other. The inconsistent prices are likely to remain on the higher note as the populations rise and urbanize, resource sourcing reaches unreachable destinations and the associated risks to the environment increases. To counter-act this backdrop, a new industrial model was necessary which would answer the questions of efficient utilization of resources and which aligns with sustainable ecological development [6, 7]. The term 'Circular economy' symbolizes a restorative design. It encompasses a cycle of using and reusing of natural sources with maximum possible efficiency throughout the life cycle of finished products and the basic principle behind being:

- Balancing the consumption of finite renewable resources and controlling and preserving finite stocks
- Circulation of the products and its basic materials in value at the best level achievable thereby leading to the optimization of resources.
- Elimination negative externalizations by implementation of effective methods.

With this expected transition, the central role of economic process will be taken over by unlimited resources like labor and the limited natural resources will play a supporting role. Numerous industries were successful in counter-action of the imbalance between supply and demand for natural resources.

3. Limitations of Linear Economy

The present scenario, which is 'take-make-dispose' model, leads to the significant wastage of finite natural resources. Even though throughout our past, the decrease of cost of resources have paved way for economic growth, this low costs of resources related to labor cost has led to the present economic model we follow which encompass wastage of resources on a significant scale. While considering the ease of getting our hands on new raw materials and the cheap cost related to the disposal of the residual, the re-usage of materials has never been our chief economic priority. Various factors affect the capability of self-correction of the system. The present rules, both accounting and managerial has let on for a wide array of secondary costs to be not put into accounts and are considered as externalities. In addition to this, certain products such as pharmaceuticals and fertilizers are to be faced with long approval periods, which is also a drawback to the change [8, 9]. The resulting model known as the linear model works in a non-complex way. Companies' source raw materials manufacture the products and sell them to their respective customers which are then discarded when the products reach their end-of-life. The resource wastes involved in this model are briefed below:

i. Misuse of raw materials during production process: Significant amount of materials are usually lost during the manufacturing processes of products mainly in the sequence amid the initial and final process. For example, SERI (Sustainable Europe Research Institute) came into conclusion that in OECD countries during their manufacturing processes expend about 21 billion tons of materials, which has no direct involvement in products themselves like elements, which has no role in economic system - like segregation of materials from mining, wood and agricultural losses, also materials from construction activities. Wastage of substances takes place in different steps during production. Field damages due to attack of pests and pathogens, production related losses due to lack of efficiency, losses happen because of inappropriate storage condition of goods and products wasted use to inefficient usage by the consumers. The global wastage contributed by the food supply chain adds up to roughly one-third of produced food per year for human consumption.

ii. Wastage by end of life: For majority of the goods, elementary manufacturing rates are greater when compared to traditional restoration rates of goods after the end of their useful life cycle. Based on quality, the global economic system saw a rise of approximately sixty-five million tons of raw materials in 2010 which is expected to rise up to eighty-two billion in 2020. In Europe, approximately only 40% of the total waste materials were recycled of the total 2.7 billion tons of waste. While the sole waste streams are taken into consideration, the present recycling rates cover only a few waste types. The latest UNEP report states approximate losses are calculated only for specific industries of certain level. Rubble created as a result of construction and demolition of buildings contributes to twenty-six percentage of the entire non-industrial solid waste produced by the United States, which consists of

countless recyclable materials from wood to steel and concrete. The complete re-usage happens only for 20–30% of all the construction and demolition wastes and this is usually because all structures are built up making them unfriendly to smashing down into recyclable or reusable components, which will ultimately lead to wastage of materials beneficial for the organization.

iii. Utilization of energy: In a linear system, whenever a material is disposed in a junkyard, it indicates the disappearance of all its residual energy. Re-usage saves more energy when compared to the merge share of energy redeemed by recycling disposed products. One of the most intense parts of the supply chain system is the usage of power resources in a linear production model. For instance, the procedures involved in extorting materials from the earth and its transformation to a commercial form favorable to access. During aluminum products manufacturing, the procedures involved in partially finished aluminum explains eighty percentage of energy absorbed. This is because of a system, which depends upon upstream production that leads to energy conservation. Upstream production means no new materials are used every time a product is manufactured and the industry along with its customers are relentless in ensuing immense recycle rates (In Ref. to the stats of UNEP, the 'end of life' rates of recycling of aluminum is between 43–70% and is higher compared to other non-ferrous metals, for example, copper (43–53%), zinc (19–52%), magnesium (39%)). While energy consumption by biological inputs is evenly extended throughout the value chain, the circular mode, which encompasses a reduced energy magnitude, leads to a decrease in the threshold energy demand and helps in the transition towards renewable energy thereby creating a virtuous cycle.

iv. Erosion of ecosystem services: Even though it's as significant as climatic change but given minor s concentration compared as the deterioration of 'ecosystem services' The benefits provided by the ecosystem that bolsters and boost up human well-being, for instance, forests which being a fundamental equivalent of atmospheric, soil and hydrological systems, take in atmospheric CO2 and releases O2, contributes to the carbon content in the soil and also regulates underwater tables --along with further other benefits, are subjected to human mismanagement. The investigation undertaken by the Millennium Ecosystem Assessment on 24 environmental services ranging from immediate services like food arrangement to much more ambitious benefits like pest control and regulation of related diseases found out that 15 out of the twenty-four benefits are corrupted. We are currently consuming beyond the capacity that can be met by the earth's ecosystem, thereby depleting the earth's natural assets. If should be backed up by an example, according to The Economics and Ecosystem and Biodiversity, China lost around 12 billion US dollars in the period between 1950 and 1998 due to deforestation. The economic growth is weighed down due the imbalances of the current economic model:

The troubles present in the current economic system followed which ignores the complete utilization of the potential of natural resources have surfaced as the increase in the commodity prices are becoming evident and also their volatility. From 2002, we have observed a continuous hike in the costs of natural resources. While referring the McKinsey's Commodity Price Index (2011), the mathematical average of the commodity sub-indices mainly metals, energy, food and other non-agricultural products, have reached a higher level when compared to past century

values. The most attention worthy commodity price hike was that of West Texas crude oil—147USD per barrel price, which was record breaking in 2008 and in addition, 107% increase in price of food grains from June 2010 to January 2011. The already weakened global economy was further subjected to blow by the sustained higher cost of resources [10–12]. Over the past years, the commodity price volatility was affected by numerous factors. Firstly, the metal prices reached a higher level, much more that their respective cost curves, due to a spike in demands—where it was forced to face the relatively high costs to produce an additional unit. This lead to a condition where a minor change in the demand can result to disproportionately large swings of resource costs. In addition, at the same time, the technological requisites for extracting numerous commodities increased due to the excessive pressure on the easy to access reserves, making malfunctions more common in area of resource accessibility, thereby causing disruptions in the supply chain. The supply dynamics has also been made vulnerable by the weather patterns and abrupt political changes. Finally, the new investors of the financial market was given access to the commodity price tags due to development and innovations in the financial market which in turn paved way to the worsening of price swings. All these factors all-together hindered the global business growth and thus the economic growth. The recent problem faced by the company Tata Steel was that the price of raw materials for the steel manufacturing faced a hike but the steel market did not rise enough to cancel off the higher material cost leading to a loss. The way the companies found out to limit their exposure to this constantly fluctuating cost swings is by hedging contracts at a cost [12–15]. The cost of hedging depends upon the credit rating of a company and the predicted changes in the market. However, in the current economic scenario, the company, which does not possess a grade credit history, will be most likely to spend more than 10% of hedged amount to financial services.

4. Circular Economy

The term Circular Economy has gained popularity in the recent times. The concept puts forth a characteristic and more defined propaganda which is restorative and regenerative by nature while maintaining its primary objective of keeping utilities, products and materials at the highest utility and values at all times. The circular economic model overlooks the presently followed take-make-waste industrial model and strives to redefine social-economical-ecological growth concentrating on positive society-wide benefits. The model progressively decouples the economic activity from over utilizing the finite natural resources and tries to eradicate waste production out of the system [16]. The circular model builds economic, natural and social capital by promoting a transition towards renewable energy resources and CE is based on three basic principles:

- Preservation of natural capital via balanced renewable resource flows and controlled finite stocks: This is carried out by dematerialization of utilities or virtual deliver of utilities. Whenever there is a need for resources, the circular system makes an educational choosing of technologies and processes which uses renewable and better performing resources wherever possible. These approaches enhance natural capital and devise conditions for regeneration.

- Circulating materials and products in the usage cycle while maintaining its highest utility: The proposed circulation is executed by designing products feasible for recycling, refurbishing and remanufacturing thereby providing towards the economy. Tighter inner loops are employed by the circulating

system whenever possible which basically means maintenance instead of recycling. This helps in preserving the embedded energy and also maximization of the consecutive cycle counts and time utilized in individual cycles by increasing product lifespan and optimization of reuse. Circular systems also boost the re-entry of bio-nutrients into the atmosphere safely for decomposition which will turn into precious raw materials for a new cycle. In case of the biological cycle, the intention behind product design is to make them consumable or metabolized by the economy and to be regenerated as a new resource value.

- Designing out negative externalities: In CE, waste does not exist as it is designed out purposely. Biological products are returned to the soil by employing biodegradable procedures as they are non-toxic. For technical materials- they are made to be recovered and upgraded there by reducing the inflow of energy and increasing the preserving value of products.

Further, CE believes that diversity important for building strength and it is considered as a major player for adaptability and flexibility. For instance, in living systems, biodiversity is very much needed for surviving environmental changes. Same as that, economies require a balance of businesses to survive and flourish in the long term. While smaller enterprises bring alternate models during crises, larger enterprises put forth volume and efficiency.

5. Value Creation for Circular Economy

- Value of a product is most preserved when it is repaired and maintained to its complete utilization. When it comes to an extend where maintenance is not recommended, then the constituents are reused or remanufactured. The practice preserves greater value against recycling the materials.

- Maximization of the count of successive cycles and/or time utilized in individual cycle for products which means number of times a product is reused or extension of a products life. The prolonged cycles of an individual product saves material, energy and labor needed to create a new one.

- Diversification of reuse practices throughout the value chain. For instance, cotton clothing can be reused and then can be crossed to the furniture industry as a fill-in for upholstery, and further the fiber can be reused in stone wool insulation for construction. This will avoid the input of unused materials into the economy, which in this case before the cotton fibers are safely returned to the biosphere.

6. Economic Impacts

- Economic growth: Economic growth can be achieved by an increase in revenues from upcoming circular practices combined with the reduction in production costs by improved efficient utilization of inputs. These purposed changes in input and output of economic production habits will have an impact on economy-wide supply, demand and prices, etc. through all economic sectors, both direct and indirect, which will add to the overall economic growth.

- Job creation: The effect on employability depends mainly on the increase in expenditure power supplemented by the reduction in prices, which is expected across sectors and also to the intensity of human labor required in high quality recycling practices and high skilled jobs in remanufacturing. Having said that the employment opportunities is not limited to the remanufacturing and growth within large corporations but is rich and diverse. There is an expected creation of jobs across industrial sectors, in small and medium enterprises, by a boost in innovation and entrepreneurship, by local reverse logistics and finally a new service-based economy.

- Innovation: The driving force of innovation is fueled by the dream to replace one-way products with products designed to align with the circular system and which will help in the creation of reverse logistics networks. The benefits attained from a much more innovative economy are energy and labor efficiency, quality improved materials, improved technological developments and increased opportunities to profit for companies.

7. Benefits of Circular Systems on Enterprises

- Increased security and decreased fluctuation of supply: The transition towards a circular system based economy basically means the utilization of less virgin material, usage of more recycled materials encompassing a higher share of labor expenses, decreasing company dealings with fluctuating raw material prices and also increased resilience. CE also decreases the threat posed by natural calamities/political issues on supply chain networks as there is an access for alternate materials provided by decentralized operators.

- Demand creation for business services: More demand for service businesses are created by the implementation of circular economies.

1. Products at the end of their life are reintroduced into the system by collection and reverse logistics companies

2. The utilization of a product to its maximum capacity or longer life cycles are made possible by product remarketers and sales platforms

3. Information and input on components remanufacturing and product refurbishment is offered by the respective specialized service businesses.

The need for specialized skills in order to collect products, disassemble, refurbish, integrate into remanufacturing and finally delivering products to customers, is imperative and this is where specialized service businesses comes to play. The current enterprises doing these processes are mostly subsidiaries of existing manufacturers, and hence there are new opportunities for new business models. Such responsible business models will help companies to attain a unique insight on product usage patterns which will further aid in the development of improved products, advanced services and also improved customer satisfaction [17–23].

8. What is Industry 4.0?

We are in the midst of a powerful transformation in terms of the way we develop products, thanks to the digitalization of the manufacturing sector. This transition

is significant in a way that it is termed as 'Industry 4.0' which defines the fourth industrial revolution ever occurred in the area of manufacturing. From the very first industrial revolution which depicted the mechanization of steam power and water, through the introduction of assembly lines and mass production using electricity in the second, the fourth industrial revolution is the continuation of the third revolution of computers and automation with a further enhancement by autonomous systems fueled by machine learning and data analytics. The definition of term 'Industry 4.0' can vary considerably depending on the point of view, but it can be easily referred as the intelligent and permanent linking and networking of machines and machine operated processes. Serious shifts are undergoing in the manufacturing sector which inevitably dismiss the claims that Industry 4.0 is merely a marketing buzzword. The introduction of computers was considered as a disruptive move during Industry 3.0 as it was an entirely new technology then but presently while Industry 4.0 unfolds, computers are interconnected and they can communicate with each other, ultimately capacitating them to make and implement decisions without the need for any human intervention. This revolution is made possible by the combination of technologies like cyber-physical systems; Internet of Things, the Internet of Systems; which will in-turn make smart factory a reality. These supporting machineries will get smarter as they gain access to more and more data, our factories will be more efficient, productive and at the same time, Sustainable. Ultimately, the true power of Industry 4.0 lies in the possibility to gather and analyze information across machines which enables quicker, more flexible and more efficient mechanism to manufacture high quality goods at reduced costs while the expected results being increased productivity, a shift in economics, industrial growth and a modification in the workforce profiles. With the emergence

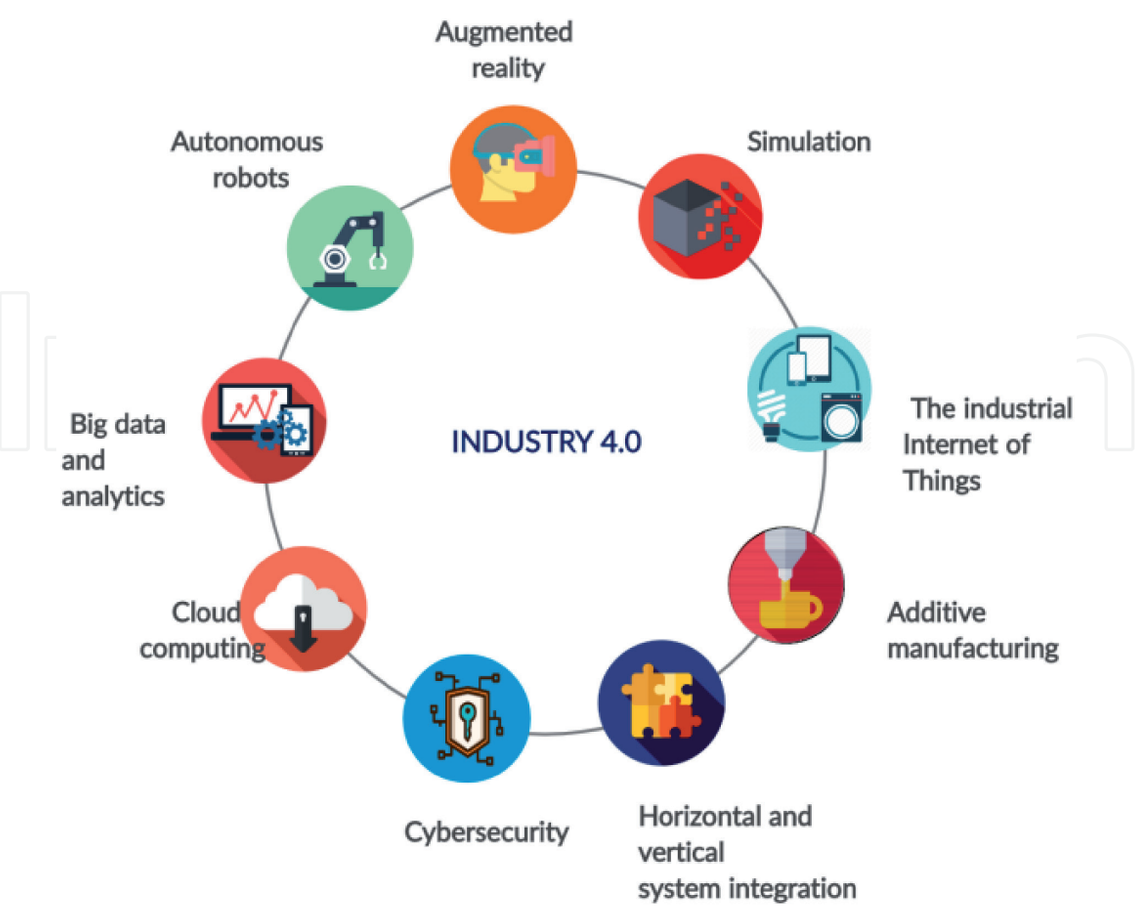

Figure 1.
Components of Industry 4.0.

of new technologies, it is indeed an exciting time for the manufacturing industry as there will be a wave of new opportunities that will help a company towards achieving improved flexibility, sustainability and productivity. The Industry 4.0 will lead this generation towards an ecosystem where humans and machines can work together, empowering businesses to achieve greater insights, reducing risks of error and to make better decisions [24–28].

Industry 4.0 incorporates three technological trends leading the transition which are connectivity, intelligence and flexible automation. I4.0 merges Operational Technology (OT) and Information Technology (IT) for creating a cyber-physical environment (**Figure 1**). This is made feasible due to the development of digital solutions and the advancement in associated technologies which include:

Once dissimilar systems and processes are now integrated across the value and supply chain by interconnected computer systems thus aiding the digital transformation. Embracing this digital transformation with the interdependence that comes along will lead to a multitude of advantages for the company encompassing improved agility, flexibility and operational performance. Even though numerous organizations are operating in denial about the implications of Industry 4.0 on their business or are striving hard to find talent or knowledge to implement the framework, several others are actively preparing towards a future of digitalization accepting that smart machines can improve their business.

9. How to promote Circular systems?

Design and production aligning to CE terms: Primarily, circular economy must be regenerative and restorative by design. Importance must be provided towards the recovery of materials and products at the design level, contrary to the practice of waiting until the end of product life cycle. Design processes should be planned and organized in a manner that will facilitate product reuse, recycle and cross industrial transfer. This intricate CE product design is to be carried out with advanced skills, insights and working plans which are not very popular in the current situation. Material selection is expected to play a critical part in designing resilient products and the manufacturers are expected to detail the purpose of the end products over the specification of materials to be used. Standardized components, design which facilitates ease end of life sorting as well as taking into consideration the usage of by-products and wastes into something useful is also preferred [29–34].

New Business models: New business models should prioritize access over ownership in order to gain more attractive value propositions as this model will transform consumers into users. Companies that can leverage their market share and capabilities in the value chain can drive circularity in the mainstream business. Profitable businesses will inspire other businesses and there is a significant potential to be expanded globally.

Reverse Cycle: For companies to attain value from products at the end of their life cycle, used products must be collected and brought back. Such value preservation will bolster the transition towards a circular economy. This is made possible by reverse logistics and treatment methods which will help those materials to get back on the market. This will be an intricate process which includes delivery chain logistics, sorting, risk management, warehousing, power generation and may even employ molecular biology and polymer chemistry. Reverse logistics network which cascade materials to be used for other purposes is to be optimized totally and must be brought under the terms of circularity. User friendly collection schematics, accessible locations for customers and specialists as well as capability to maintain the quality throughout the diverse applications of the collected products are to be

provided significant importance. Efficient reverse cycle will be cost effective, will have a better quality collection and also will employ efficient and effective segmentation of utilized products thereby resulting in the decrement of loss of materials outside the system in turn aiding circular design.

9.1 Advantages of Circular Economy

The world population is growing at alarming rate, so is the usage of natural resources. We will reach to a point where the nature will be depleted of the resources and will not have any to offer the human race. This is when circular economy benefits on a global scale. In addition to using up the resources, the development these days has an adverse effect on the environment. Moving towards a circular economy could offer reduced pressure on the environment. The wastes those are otherwise discarded to the environment are instead recycled and made to use up to its maximum potential. This could improve the security and availability of the natural resources, which are the raw materials for the production processes. This will increase competitiveness among the companies and bring about more innovation, which in turn will boost the economic growth. The economic growth is marked with creating more jobs and other opportunities. Circular economy can also help companies provide more durable and innovative goods with increased quality of life, which help consumers save money in the end [35–37]. According to waste management priority order, the first and foremost priority is to reduce the amount of wastes generated. It is followed by reuse, recycle and other recovery procedures. Disposal of waste to environment is the least desirable waste management procedure. This exactly aligns with the characteristics of a circular economy.

9.2 Circular Economy and Sustainability

It combines the scientific disciplines of management, economy, technology, engineering, environment and society. As circular economy is essential today to promote the goals of sustainable development and all these scientific areas are not independent, their connections and synergies exist and should be further developed. Multidisciplinary approaches and numerous connections between these scientific areas are mandatory to reach the sustainability goals and to solve environmental problems, expand technological limits and overcome potential economic disturbances. This approach is expressed with new policies (market-based instruments, command and control, and circular public procurement), technological suggestions (e.g. technical cycle solutions), environmental engineering technologies (e.g., waste management, 3R strategies, water recycle, wastewater treatment and reuse, renewable energy), circular business models, circular innovations, circular management solutions, consumers' behaviour in circular economy, new circular economy products labels and social acceptance in circular economy.

Journal information.

Nowadays, in the recognized economic systems, goods and services are used, created, and rejected, there is a well-defined pattern in linear economy, where the flow has a clear start and end. The circular economy works relatively differently, the services and products in a circular economy are intended to reused or recycled both in technical or biological cycles. All the products are synthesized in such a way that they can be easily take to bits and the materials used will either be broken down by natural process or returned to fabrication of any other product. The main advantage is that it will reduce the demand on earth's finite resources, also the waste or unwanted residues from industry can be used as resources for another industry. It also provides a well-defined framework that put together approaches and methods

from diverse foundations like biomimicry, cradle-to-cradle, ecosystem services, industrial symbiosis, and collective consumption. The circular economy is evidently a diverse way to do business, obliging the establishments to rethink everything starting from resource procurement, design and final manufacture of the products or services. Advocates of the circular economy propose a sustainable world, in which there will not be any depreciation in the standard of life the consumers and can be easily attained without any economic loss of revenue or additional costs for manufacturers and also the quality of the product or services.

Following are the principles that define **how the circular economy should work in the present scenario:**

1. **Any waste is a resource:** All the biodegradable and non-biodegradable materials are use again.

2. **Second hand use**: The product can be reintroduced in the economic circuit after the use by the initial consumers

3. **Reuse**: Some products or certain parts of those products that still work can be reused to elaborate new artifacts.

4. **Repare**: the damage products can be repaired and can be used.

5. **Recycle**: Making value added products from waste materials discarded in waste with or without minor addition or deletion.

6. **Valorization**: hitch energy from waste that cannot be recycled further.

7. **Functionality economy**: it establishes a system of rental property. After the use of the particular product, it is returned to the producer, it is dismantled and the effective parts can be reused.

8. **Relying on energy from renewable sources**: rejection of demand on the finite fossil fuels resources for the manufacture of the product, recycle and reuse.

9. **Eco-design**: This reflects and incorporates in its beginning, the environmental impacts throughout the life cycle of a product i.e. from cradle to grave.

10. **Territorial Industrial and ecology**: instituting of an industrial organizational method in an area/territory branded by an augmented management of resources, flows of resources, stocks, services and wastes.

10. Industry 4.0 as Facilitator for Sustainable Development

The increasing needs and multiplying wants of human beings resulted in the overexploitation of the natural resources. From the primitive cave man to the present computer oriented man, both the volume and methods of natural resources exploitation have undergone tremendous changes. But modern research in science and technology has resulted either in the improved versions of already existing ones or in the inventions of the new ones at the cost of limited natural resources. As a result, the luxuries are becoming comforts and comforts are becoming necessities. Resources are limited, but people's wants are unlimited. Therefore, limited resources need to be used carefully through efficient allocation among the various

alternative uses. The rising socio-economic inequality, growing environmental degradation, climate change, urban sprawl and ever increasing cyber-dependency can be underlined as the global tendencies and this may result in social instability, natural catastrophes, water crises, pollution, heavy resource depletion, unemployment and migration throughout the globe [38–43].

After the UN General Assembly in 2015, implemented the Agenda 2030- which amounts seventeen inseparable and self-sustaining goals called Millennium Sustainable Development Goals are envisioned to function as a foundation stone for the renovation of the global economies towards sustainable development. This alteration procedure must result in economic development in agreement with equal opportunity, social uniqueness within the so-called ecological margins. As indispensable investors' for sustainable development, industrial establishments have to move towards an innovative archetype which places much prominence on sustainable value creation. The industrial value creation has undergone thorough changes starting from the age of discovery of fire to the industrial revolution throughout the years. Industry 4.0 (The fourth industrial revolution) which was initiated in 2010s, the ultramodern concept of technology and research for Industry 4.0 and sustainability are highlighted. In response to the Agenda –2030, the European Union released an outline for action, which collectively tells about the planet, people, peace and prosperity [17]. As indispensible stakeholders for sustainable development, all the industrial organizations have to move towards an innovative manufacturing pattern which puts importance on both sustainable development goals together with value creation.The sustainable value creation has three dimensions, such as economic, social and environmental.

The major objectives of industry 4.0 include, linking services, resources and humans in real-time during the making on the basis of CPS (Cyber Physical Systems) and the Internet of Things (IoT). The major physical systems consist of several actuators, sensors, embedded data handling soft wares which enables fast processing and communication of data to different interfaces. There is complete automation in all the systems, process, manufacturing, packing, error maintenance, which helps in easy maintenance and control of the complete system.The value making elements in Industry 4.0 are, Business Models, Value Creation Network and Product Life Cycle, Product, Process, Organization and Equipment.

11. Importance of Sustainable Manufacture in Industry 4.0

The World Commission on Environment and Development (WCED) was appointed in 1983 by the UN to study the relationship between environment and development and it submitted the report in 1987-Our Common Future'. After the publication of 'Our common Future' in 1987, the concept of sustainable development came in to being and is defined as the development which meets the needs of the present generation without compromising the ability of future generations to meet their needs [20]. Sustainable development provides a healthy model for the progress of the world. Sustainable development involves the eco-economic management of resources to reach an optimum level of use and satisfaction, instead of maximum level. It also involves the restoration of degraded resources, maintenance of production and the elaboration of resource base by the wise use of the renewable resources.

As development involves a progressive transformation of the society in all aspects, sustainable development indicates the uninterrupted continuity of the improvement of social, economic. Ethical, scientific, technological, educational and spiritual condition. Thus it is an all-round human development of an integrated

or holistic nature. Sustainable development necessitates the rate of depletion of non-renewable resource to be reduced to make future options possible. The national strategies suggested by the WCED for attaining the concept of sustainable development are revitalizing growth, meeting crucial needs for jobs, water, sanitation and energy, guaranteeing sustainable level of population, reorienting technology, conserving and enhancing the resource bases and handling risks and integration of environment and economics in the final decision making [21–24].

Interaction between economic growth and development fully depends on the natural resources and human resources. The attitude of human beings determines both the content of growth in material and energy terms and its impact in terms of equity. Now both developing and developed countries are in the process of evolving sound methodologies to estimate the real stock and the value of national disasters, providing larger and better opportunities for education and health, assessing social and ecological costs of development projects and taking decisions less vulnerability to economic crisis and these resources that are not exploited in enterprises or national accounts. Only if the quantity of decrease in the deterioration of the natural resources and the conditions along with human resources are calculated we will be able to estimate whether growth is quantitatively acceptable or not. Equitable distribution of income, less vulnerability to economic crisis and national disasters, providing larger and better opportunities for education and health, assessing the social and ecological costs of development projects and taking decisions based on it etc. are the different aspects of improving the quality of growth in order to attain sustainable development. Thus sustainable development can accelerate and assure social welfare by taking steps to improve both natural and human resources.

The approach of sustainability comprises of three pillars which include, the economic, environmental and social dimensions as ultimate and integrative arenas of action. Environmental sustainability designates the conservation and existences of the whole ecological complexes, which is both, a source as well as a sink of natural resources and anthropogenic activities. Social sustainability comprises of the equitable sharing of human resources, taking into consideration about the age groups, social classes, gender, and regional distinctiveness together with social justice and solidarity. Economic sustainability needs the keeping of modest benefits and efficient market orientation together with targeting at the conservation of the available resources and thereby increasing the standard of life. Sustainable development involves the eco-economic managing of resources to reach an optimal level of use and satisfaction, instead of maximum level. It also involves the restoration of degraded resources, maintenance of production resources and the enlargement of resource base by the judicious use of the renewable resources.

12. Decision Making with Environmental and Economic Considerations

Economic decisions of the past were taken mainly on the basis of the market value generated as a consequence of implementing the decisions. But quite often markets do not represent the real costs and benefits involved in a particular production process. Therefore reflecting the hidden costs and benefits mainly environmental became a major concern of modern policy makers and planners who aim at sustainable development. Integrating economic and environmental concern proper changes in attitudes and institutional arrangements have become the hall mark of most modern developmental models. Ecological and economic interactions and interdependence and testified through trade, finance, investment and travel. Hence sustainable development requires the association of ecology and economics in order to promote development and safeguard environment.

In the final phase of suggesting essential requirements for attaining sustainable development, the World Commission puts forward the presence of the following systems.

- A political system that fortifies effective citizen's participation in the final decision making.
- An economic system which is able to create technical knowledge on a self-contained and sustainable basis.
- A social system that offers solutions to the pressures arising from discordant development.
- A production system which compliments the responsibility of the presence of the ecological basis for the development.
- A technological system that can explore unremittingly for new clarifications
- An international system that nurtures sustainability patterns of trade and business.
- An administrative system that is very flexible and has the capability of self-correction.

These necessities actually depict the different dimensions of sustainable development. Unless sincere, omniscient, integrated and harmonious changes in attitude take place from the bottom of human hearts, sustainable development will remain a distant dream.

13. Carrying Capacity based Resource Consumption

Carrying capacity is the number of human beings, which can be sustained in a specified area together with the natural resource limits without degrading the social, economic natural and cultural environment for the present and coming generations. The carrying capacity of every system is the maximum amount of resources it can provide and maximum amount of residuals or wastes it can assimilate. Man as an organism has a carrying capacity to use the resources and dump the waste/byproducts back to the environment like any other organism in the universe. If the population of a specific organism is well below the carrying capacity of the environment, it will support positively for natural increase in the number of organisms of the particular species. Several reports are there regarding the carrying capacity of the earth for humans' shows that it has been exceeded far above the normal rate the biosphere can sustain. If carrying capacity of the biosphere is exceeded, living organisms must acclimatize to the new levels of consumption or find alternative resources for meeting their needs. As there is rapid rise in population, the demand for natural resources is increasing in an alarming rate also the pollution load and environmental degradation results. However, through effective management systems and development of new resource saving technologies, we can sustain with limited resources available.

The world Summit, 2002 identified key objectives of sustainable development: protecting natural resources, eradicating poverty and changing unsustainable consumption and production patterns. A multidisciplinary team including

technologists, ecologists, economists and policy analysts has to ascertain the consumption pattern globally and determine the human carrying capacity and come up with sustainable solutions in which we are considering both environment and economic development equally. The carrying capacity can be changed by improving the technological advancements. As the system exceeds its natural carrying capacity, leaving the environment no longer able to support even the original number of people inhabiting in the area on a sustainable basis [41–46].

14. Conclusion

For development, we need resources, due to rapid increase in population, urbanization, industrialization the resource depletion is increasing in an alarming rate. We cannot avoid development; we are not able to change to the bullock cart age, so we have to find alternatives for the sustainable use of available resources. We will reach to a point where the nature will be depleted of the resources and will not have any to offer the human race. This is when circular economy benefits on a global scale. In addition to using up the resources, the development these days has an adverse effect on the environment. Moving towards a circular economy could offer reduced pressure on the environment. The wastes those are otherwise discarded to the environment are instead recycled and made to use up to its maximum potential. This could improve the security and availability of the natural resources, which are the raw materials for the production processes. This will increase competitiveness among the companies and bring about more innovation, which in turn will boost the economic growth. The economic growth is marked with creating more jobs and other opportunities. Circular economy can also help companies provide more durable and innovative goods with increased quality of life, which help consumers save money in the end. According to waste management priority order, the first and foremost priority is to reduce the amount of wastes generated. We can follow the reuse, recycle and other recovery procedures. Disposal of waste to environment is the least desirable waste management procedure. This exactly aligns with the characteristics of a circular economy, finally can attain in sustainable future also.

The present work evaluated the prospective of industrial value creation in Industry 4.0 in terms of their involvement to sustainable development. The importance of the study was to put together the social, economic and environmental dimensions of sustainability. The fundamentals concepts of Industry 4.0 and its basic technologies for value development in the context of Industry 4.0, as well as of sustainable value creation were delineated. This work also aims to propose a novel sustainability approach in industrial environment, especially in environment management systems in industries in order to achieve better performance in terms of both economic and environmental perspectives. The work also supports the engineering systems to be sustainable and feasible industrial systems that can support a transition to the circular economy by change in their process, product and approach finally help them to act in fruitful congruence with the recuperative mechanisms of the Mother Nature. Also results in less demand on the earth's natural resources and less impact on environment. The challenge involves complex array of issues and problems that require more sustainable solutions than that are usually done as the end-of pipe-remedies. Hence there is urgent need for environment management together with the incorporation of principles of sustainable development.

Nowadays growing attention has been modeled to enhance the sustainability component in the manufacturing process by decreasing the consumption of natural resources and its key materials, the energy consumption and the ecological footprint which also increases the company's acceptability and competiveness

in global markets. The rebuilding comprises of a set of processes or systems, tools and knowledge based approaches to reuse and recover functions and valuable materials from industrial waste products and postconsumer products under a circular economy perspective. Globally the industries are facing several challenges to attain the reasonable and sustainable health by upholding peaceful and good relationship between the societies and the biosphere. To overcome these challenges the components of industry 4.0 is set to achieve sustainable development in three dimensions- economic, ecological and social. The new evolution of the production and industrial process called Industry 4.0, and its related technologies such as the cyber–physical systems, big data analytics and Internet of Things, still have an unidentified potential influence on the environment. Though, the existing economic strategies and the resultant business models are more or less universal, they largely neglect the organizational essentials. The closed-loop economy or circular economy present modewort on debate on sustainable development as it an approach in which the waste or residuals from an industry can be used as raw material for another industry there by reducing the demand on earth's natural resources. The vital aim of the work is to bond the gap between organizational characteristics, such as profitability, market position, structure, decision-making style and the adoption of circular economy practices.

Conflict of interest

The authors certify that there will not exists any conflict of interest in the subject matter or materials discussed in this manuscript.

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