Emerging Industrial Revolution: Symbiosis of Industry 4.0 and Circular Economy: The Role of Universities

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Growing consumerism and population worldwide raises concerns about society's sustainability aspirations. This has led to calls for concerted efforts to shift from the linear economy to a circular economy (CE), which are gaining momentum globally. CE approaches lead to a zero-waste scenario of economic growth and sustainable development. These approaches are based on semi-scientific and empirical concepts with technologies enabling 3Rs (reduce, reuse, recycle) and 6Rs (reuse, recycle, redesign, remanufacture, reduce, recover). Studies estimate that the transition to a CE would save the world in excess of a trillion dollars annually while creating new jobs, business opportunities and economic growth. The emerging industrial revolution will enhance the symbiotic pursuit of new technologies and CE to transform extant production systems and business models for sustainability. This article examines the trends, availability and readiness of fourth industrial revolution (4IR or industry 4.0) technologies (for example, Internet of Things [IoT], artificial intelligence [AI] and nanotechnology) to support and promote CE transitions within the higher education institutional context. Furthermore, it elucidates the role of universities as living laboratories for experimenting the utility of industry 4.0 technologies in driving the shift towards CE futures. The article concludes that universities should play a pivotal role in engendering CE transitions.

Keywords: Industry 4.0 technologies, circular economy, innovation, higher education

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Introduction

The First Industrial revolution was based on steam and waterpower, the second on electricity and assembly lines and the third on automation. Each of these industrial revolutions were characterised by advances in technology. Different from the first three revolutions, the fourth industrial revolution (4IR or industry 4.0) is characterised by the parallel development of a swath of seemingly independent technologies, each with world-changing potential. These advances each promise huge benefits to society. However, the 4IR also poses serious challenges in terms of realignment of labour markets and supply chains, skills shortage and disruptive business models (Ramakrishna et al., 2017).

As with previous industrial revolutions, the 4IR fundamentally transforms the way we live, work and govern ourselves. However, the nature of the 4IR differs fundamentally from its predecessors due to both the speed and magnitude of the change facing us. As new technologies will come from a range of fields, it is harder than ever to see where opportunities and risks lie (Schwab, 2016, 2018). Circular economy (CE) remains a potential beneficiary of the 4IR. Accordingly, the CE vision of nations and businesses will be realised fully from the development of 4IR technologies, therefore indicating a symbiotic relationship potential. Previously, the produce–use–throw (linear economy) growth model was favoured by economies and companies based on the availability of plentiful and inexpensive natural resources. Indeed, when resources are abundant and inexpensive and the impact on the environment is not a prevailing concern, the 'linear' approach to satisfying demand remains prevalent. Companies are able, with ever-increasing efficiency, to extract raw materials, use those materials as inputs to the manufacturing of desired products and sell them to as many customers as possible, who use and discard them after the products have served their purpose. Companies intentionally design products to become obsolete in shorter periods so that they can release newer models every year and sell more, fuelling consumerism further (Ramakrishna, 2018).

However, the world is rapidly approaching a point at which the linear model is no longer viable due to rising global affluence as the availability of many non-renewables (including metals, minerals and fossil fuel) cannot keep up with the demand; the regenerative capacity of renewables (such as land, forests, water) becomes strained to its limits and the planetary boundaries become threatened as never before. Negative effects of the current growth model are already being reported on all continents (IPCC, 2014; National Climate Assessment, 2014).

The CE is a viable growth model that can radically improve resource productivity to reverse these trends. It can also drive greater innovation and job creation. Furthermore, it promises to transform the dynamics of competitiveness and bestow real competitive advantage to early movers. At its core, CE is about creating new value chains that decouple growth from the use of scarce and linear resource inputs, that is, inputs that cannot be returned and used in cyclical chains. This can be accomplished in several ways. For instance, a company could promote using 'lasting' resources to break the link between scarcity and economic activity by deploying only inputs that can be continuously reused, reprocessed or renewed for productive use (e.g., renewable energy, biomaterial or fully recycled/recyclable resources). Or, it could create more 'liquidity' in markets by making products and assets more accessible and easier to convert between users, eliminating idle time and increasing the number of people who benefit from a given volume of goods. It could develop linked value chains, reclaiming and looping back waste outputs as useful inputs into a new production process. Or, it could simply extend the useful life cycle of existing products.

Underlying concepts of CE like 'cradle to cradle', industrial ecology, biomimicry and others have been around for decades and meritoriously explored by pioneers like Bill McDonough, Michael Braungart, Walter R. Stahel and Ellen MacArthur (Accenture, 2014).

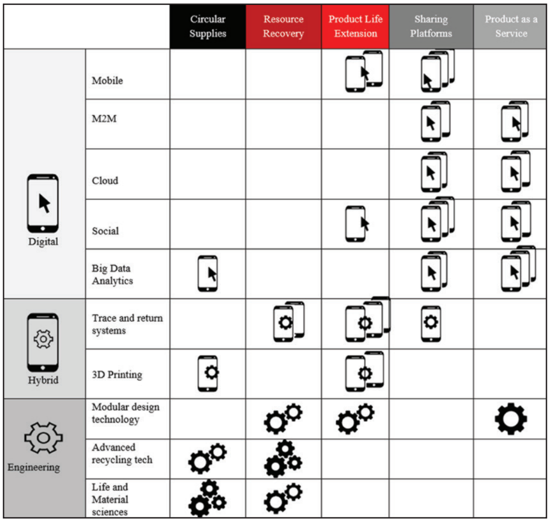
However, what makes CE so ripe for widespread adoption now is the emergence of disruptive technologies which allow radical innovation and massive change that would have been impossible a decade ago. Disruptive technologies used by pioneers to launch and operate circular business models are shown in Figure 1 (Accenture, 2014).

The data captured in Figure 1 is based on more than 120 case studies and 50 interviews. The number of icons in each box indicates relative importance.

Thus, CE is a digital revolution as much as a sustainable one which lies at the heart of the 4IR. Its attractiveness stems from its clear environmental benefits while simultaneously driving entirely new revenues and business models (Ramakrishna, 2018).

FIGURE 1

Disruptive Technologies Used by Pioneers to Launch and Operate Circular Business Models



Source: Accenture (2014).

Availability and Readiness of Industry 4.0 Technologies

Although at the conceptual level there is a strong and intuitive business case behind CE both in the short term and in the long term, it is not easy at the practical level because most companies today are simply not built to capitalise on the opportunities CE presents. Their strategies, structures and operations are deeply rooted in the linear approach to growth. For these companies to embrace CE, they need to develop business models that are free from linear thinking constraints.

Five underlying business models have been identified as generating resource productivity improvements in innovative ways: circular supplies, resource recovery, product life extension, sharing platforms and product as a service (Accenture, 2014). However, these models would not be possible without the support of innovative new technologies, especially digital ones. Designing value chains to embed circular business models, all the way through to the customer's use and return, is a major new frontier that revolutionises levels of service and flexibility, wherein the physical and digital worlds merge and products start to flow between users, markets and lifecycles at very low transaction costs (Accenture, 2014).

Disruptive technologies commonly used by the leading CE companies fall into three categories: digital (information technology), engineering (physical technology) and hybrids of the two (Accenture, 2014). These are described briefly as follows:

1. **Digital technologies**
   These technologies play an important role in establishing real-time information exchanges among users, machines and management systems. These technologies are intrinsically customer-focused and provide the information and connections needed to maintain a relationship far beyond the point of sale.
   For instance, telecommunication, in-mobile functionality and analytics enable customers to automatically get a quote for the buyback value of a used product, such as a phone, and support in returning it to a nearby store for instant reimbursement (White, 2014). Such connections enhance remote visibility and control of assets, which are especially critical for the product as a service, sharing platforms and product life extension business models. By altering the way businesses and consumers interact with physical and digital assets and by enabling dematerialisation, digital technologies can transform value chains so that they are decoupled from the need for additional resources for growth.

2. **Engineering technologies**
   These include advanced recycling, modular design, robotics, materials informatics, redesigned products suitable for circularity and life and material sciences. These enable the manufacturing of new goods from regenerated resources, as well as the actual collection, return and processing of goods and materials and cost-efficient collection of used assets for remanufacturing.

This makes these technologies especially important for running circular supplies and resource recovery models.

3. **Hybrid technology**
   This is partly digital and partly engineering. It establishes a unique type of control over assets and material flows. It allows a company to digitally identify the history, location, status and application of materials and goods while, at the same time, supporting ways to physically collect, treat and reprocess them. For example, 3D printing allows for the local manufacturing of downloadable digital designs into physical objects. Trace-and-return systems, like those by Scanimetrics, represent another key hybrid solution. Scanimetrics offers hardware, software and support for condition monitoring that is vital for low-cost predictive maintenance and repair/remanufacturing chains. Hybrid technologies play an important role in supporting circular supplies, resource recovery and product life extension models, serving as the bridge between the digital and physical worlds.

These disruptive technologies are in a nutshell, networked sensors that generate granular data to help track resources in supply chains or manufacturing processes.

Other than the disruptive technologies described above, the following industry 4.0 technologies are equally applicable:

1. **Internet of Things (IoT)**
   At the core of digitisation is the infrastructure necessary to connect everyone and everything, namely the IoT. This involves deploying a network of sensors that collect data and provide greater insights into the flow of materials, products and information. This data can be analysed to make smarter decisions on how we consume resources and how we design our systems. The Finnish company Enevo, for instance, builds and installs sensors that collect and analyse data from waste bins. These sensors provide information on when trash bins are full, allowing Enevo's systems to optimise pick-up routes for trucks. As a result, Enevo's customers report savings of 20 to 40 per cent, thanks to a reduction in fuel consumption and costs related to truck maintenance and labour, due to fewer collections being made (SmartBin.com, 2014). Moreover, advanced robotics and automation solutions facilitate automatic sorting and management of solid waste. They are being applied to diverse solid waste streams such as household waste, industrial waste and growing electrical and electronic waste or E-waste.

2. **Artificial intelligence (AI)**
   AI at a more advanced stage has led to breakthroughs such as autonomous vehicles, which can fundamentally alter not only how we move but also how we build and design where we live. Cars today are largely owned and are parked most of the time. With autonomous vehicles, cars would no longer

be owned but shared across different owners. These cars would also be constantly driving around cities to pick up and drop off passengers, significantly increasing their utilisation, reducing the need for more cars and minimising congestion in cities. Cities around the world are already piloting autonomous vehicle programs in partnership with various technology companies. One such example is nuTonomy, which has piloted autonomous vehicles in Singapore since 2016. Their initial pilot program had six autonomous vehicles, modified Renault Zoes and Mitsubishi i-MiEVs, offering rides from predetermined pick-up and drop-off points within a 2.5 mi^2 radius. Since then, nuTonomy has partnered with a local ride-sharing company, Grab, to conduct further tests and plans to launch a commercial service in 2018 (Censi, 2017; Censi & Murray, 2015).

3. **Blockchain**
   Beyond being the foundational technology for cryptocurrency, Blockchain has the power to transform supply chains across a variety of industries. It has the potential to be applied in tagging products and components to enable after-use collection, sorting, waste management and repurposing. Blockchain essentially works by providing everyone with a public ledger, which is a record of all transactions that have occurred between different parties. Every time a new transaction occurs, the public ledger is automatically updated, and everyone is instantly notified. The technology primarily aims to address issues of trust and transparency between parties. When applied to supply chains, this technology can fundamentally transform how various actors interact.

One such example of how transformative this technology can be is Bext360. The company is utilising the IoT, Blockchain and AI to make the coffee supply chain fair and transparent. Coffee farmers who harvest beans place them into a BextMachine, which uses AI to analyse the beans and grade them on quality standards. These are then recorded on the blockchain to instantly track and monitor which farm and which farmer should be paid and how much. The farmers are then paid digitally via a mobile app. From there, the beans are tracked and traced all the way from the farm to roasters to retailers to consumers. Each of these transactions is recorded on the blockchain and made available to all parties, allowing the entire chain to use the data to optimise supply chain inefficiencies, increase compensation to farmers and enable consumers to truly understand where their products come from (Bext360, 2017).

When applied to other industries, this technology can dramatically increase transparency, reduce transaction costs for verification and certification, enable smart contracting and inventory accounting and ensure fair payments across the value chain.

However, while technology has a massive transformative power to advance CE transitions, proper planning is needed as technology remains an enabler. As we increasingly utilise and incorporate digital technologies, various policies, ethical questions and unintended consequences need to be discussed and evaluated. We need to consider the use and consequences of digital technology in the long term to ensure that these technologies truly lead to circular outcomes and do not just improve linear efficiency.

Sectors of the Economy That Will Have the Most Impact

The following six potential CE activities will have the most impact on improving performance and reducing costs, as indicated in Figure 2:

FIGURE 2

Potential Circular Economy Activities Improving Performance and Reducing Costs

High profit potential   Medium profit potential   Low profit potential

Economic activities	Regenerate	Share	Optimize	Loop	Virtualize	Exchange
Information and communication services, media, and telecommunications	Low	Medium	Medium	Low	High	
Scientific R&D; other professional, scientific, and technical activities	Low	Medium	Medium	Low	High	Low
Education	Low	Medium	Medium	Low	High	Low
Human-health and social-work activities	Low	Medium	Medium	Low	High	Low
Administrative and support services	Low	Medium	Medium	Low	High	Low
Arts, entertainment, and recreation	Low	Medium	Medium	Low	High	Low
Financial and insurance activities	Low	Medium	Medium	Low	High	Low
Legal and accounting, head-office consulting, and architecture	Low	Medium	Medium	Low	High	Low
Distributive trades (including wholesale and retail trade)	High	High	Medium	Medium	High	Medium
Manufacture of wood and paper products; printing	High	High	Medium	Low	High	Low
Public administration and defence; compulsory social security	Low	High	Medium	Medium	High	Medium
Real-estate activities	Low	High	Medium	Low	Medium	Low
Manufacture of textiles, apparel, leather, and related products	High	High	Medium	Low	Medium	Medium
Construction	Low	High	Medium	High	Medium	Medium
Manufacture of transport equipment	Low	High	Medium	High	High	Medium
Manufacture of furniture	High	High	Medium	Medium	Low	Low
Water supply, waste, and remediation	High	Medium	Medium	Low	Low	Medium
Manufacture of electrical equipment; computer, electronic, and optical products	Low	Medium	Medium	High	Medium	Medium
Manufacture of machinery and equipment	Low	Medium	Medium	High	Medium	Medium
Manufacture of rubber, plastics, and basic and fabricated metal products	Medium	Medium	Medium	High	Low	High
Transportation and storage	Low	Medium	Medium	High	Low	High
Agriculture, forestry, and fishing	High	Low	Medium	Low	Low	High
Manufacture of food, beverages, and tobacco products	High	Low	Medium	High	Low	High
Mining and quarrying	Low	Low	Medium	High	Low	High
Electricity, gas, steam, and air-conditioning supply	High	Low	Medium	Medium	High	High
Manufacture of coke, refined petroleum, and chemicals products	Low	Low	Medium	Medium	Low	High
Manufacture of pharmaceuticals, medicinal chemicals, and botanicals	Medium	Low	Medium	Medium	Low	Medium
Accommodation and food-service activities	Medium	High	Medium	Medium	High	Low

Source: Ellen MacArthur Foundation and McKinsey Center for Business and Environment (2015).

1. **Regenerate:** Shift to renewable energy and materials; reclaim, retain and regenerate the health of ecosystems; and return recovered biological resources to the biosphere.
2. **Share:** Maximise utilisation of products through peer-to-peer sharing of privately owned products or public sharing of pools of products; reuse them throughout their technical life spans; and prolong those life spans through maintenance, repair and design for durability, for example, home-sharing business models.
3. **Optimise:** Improve the performance and efficiency of products; remove waste from their supply chains; and leverage big data, automation and remote sensing. None of these actions requires changing products or technologies.
4. **Loop:** Keep components and materials in closed loops and prioritise the inner ones. For finite materials, this means remanufacturing products or components and (as a last resort) recycling materials, as Michelin, the tyre company, is doing. For renewable materials, it involves anaerobic digestion and the extraction of biochemicals from organic waste.
5. **Virtualise:** Deliver utility virtually—books or music, online shopping, fleets of autonomous vehicles and virtual offices.
6. **Exchange:** Replace old materials with advanced renewable ones; and apply new technologies, such as 3D printing and electric engines.

In addition to the above, redesigning of products is another strongly emerging CE activity. Products are designed for easy disassembly whilst making components suitable for reuse and remanufacturing. They are made from materials from regenerative sources which are suitable for recycling, upcycling or degradation with no harmful effects on environment.

Industries and Businesses That Will be Benefitted by the Circular Economy

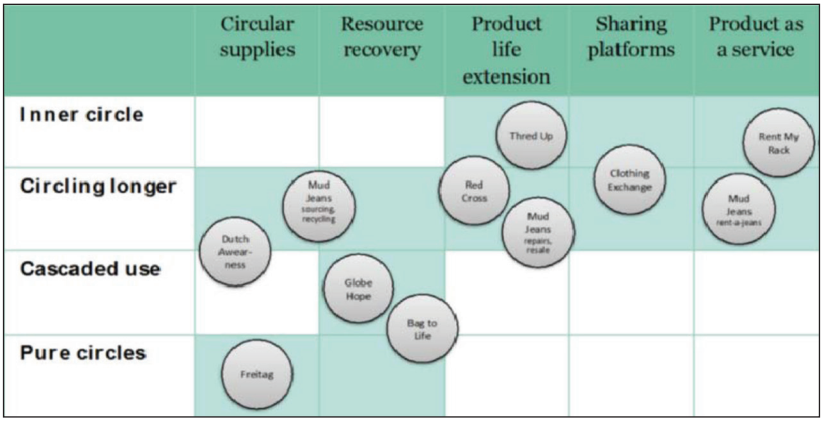
Apparel and Footwear

CE transitions hold salient potentials for the apparel industry. The industry only trails big oil when it comes to environmental impact as it is responsible for 10 per cent of global carbon emissions. Also, it is responsible for 17–20 per cent of all industrial water pollution, not to mention the logging that takes place in the world's rainforests to supply certain materials for this industry. After the exhaustion of resources to make clothing, the current practice is to throw them away when no longer needed.

Nevertheless, there has been an acknowledgment of these issues, and companies have started to look for solutions. A circular perspective can help many industries cut costs and improve performance. Also, the accentuation of the debilitating impact of the industry activities on the environment has brought about increased consideration by policymakers in different parts of the world. In furtherance to this is the need to accommodate increasing consumer expectations synonymous

FIGURE 3

Textile Company Examples Related to the Business Model Frameworks



Source: Guldmann (2016).

with the desire for cheap and readily disposable fashion, which puts considerable pressure on scarce resources.

As such, a transition from the hitherto prevalent linear business models to circular business models through any or a combination of the following value creation bases is increasingly becoming a norm in the sector. Such bases include power of the inner circle, power of circling longer, power of cascaded use and power of pure circles (Guldmann, 2016). Figure 3 shows examples of companies operating in the sector alongside the associated value creation nexus. Also, it details the relationship between the value creation bases and the circular business model variant adopted by organisations.

According to Guldmann (2016), a list of readily available case studies abounds in this sector. The author provides a catalogue of such cases as well as their distinctive strides towards CE business models. Nudie Jeans Co happens to be one of such case studies. Nudie is a menswear company which is based in Sweden. The company's main business lies in the design and manufacture of jean denims made from 100 per cent organic cotton. In this entity, customers are offered a 20 per cent discount on new jeans purchase upon the return of an old pair of jeans in-store based on a return system. Upon receipt of these jeans, Nudie carries out an assessment of the fabric to determine if they can be reused or recycled. In the case of the former, the returned jean pairs are washed, repaired and sold as second-hand goods, whereas in the latter, the company adopts any of three recycling approaches: special denim recycling project; design and production of a limited edition version of jeans made from a juxtaposition of recycled denim material and virgin cotton fibres; and a rag–rug project for the production of rugs from the returned materials.

Better World Fashion (BWF) is another fashion-based company with interests in sustaining product circularity in the face of fast-changing fashion trends which had increased the demand for materials. This aspiration is evident in the stipulated aim of the company's business model: 'offering high-quality, durable goods with a business model that embraces changing styles and preferences' (Ellen MacArthur Foundation, 2017a). Yet, BWF specialises in leather-based products, a choice driven by the longevity of leather and its ability to appear better upon frequent usage. Under the BWF arrangement, customers are expected to purchase jackets either through a monthly lease arrangement or an outright purchase. The latter has a buyback option which enables those who have purchased leather items from BWF to return the same to them when they are done wearing them. The return of such items allows them to benefit from a 50 per cent discount on new purchases. Also, when the jackets reach their reuse and repair limit, they are subsequently deployed towards the manufacture of bags and other smaller leather accessories.

According to Guldmann (2016), other entities are making new and unique garments using materials that have resulted from leftover and discarded textile materials. One such company is Globe Hope—a Finnish company. At Global Hope, materials such as advertising banners, sails, vintage fabrics, etc. are deployed towards the design and production of new materials. Companies like Global Hope remain concerned with the recycling and remanufacturing of materials which were hitherto considered as waste.

In the furniture subsector of the fabrics, apparel, carpets and textile sector, companies like Furnishare have adopted approaches towards mainstreaming CE tenets into their operations and product offerings. According to Ellen MacArthur Foundation (2017b), Furnishare was set up in 2014 to provide an online marketplace for exchanging used furniture between hypothetical buyers and sellers, thereby ensuring that such assets are kept in circulation for longer use periods before eventual recycle or remanufacture. Furnishare' s emergence was intended to contribute towards reducing the incineration or landfilling of used furniture in the United States. Furnishare' s value proposition dwells on convenience, choice, affordability and quality (Ellen MacArthur Foundation, 2017b). Under the Furnishare arrangement, owners of unwanted furniture contact the company expressing their desire to part with their furniture. Representatives of Furnishare attend to this request by inspecting and collecting the piece of furniture from the owners for display on the Furnishare online portal. Interested parties can view the items and, subsequently, lease the same through a subscription service for a fee that is supposedly a ninth of what obtains in the traditional rental stores (Ellen MacArthur Foundation, 2017b). The accruing revenue from the lease is shared between Furnishare and the owner of the furniture over an agreed-upon period.

Retail and Resale/Fast-moving Consumer Goods

This is an industry where CE has gained hold. The internet has become a platform for connecting buyers and sellers. With the emergence of apps and social media, some companies have copied eBay's model for enabling the CE for more niche items, like women's clothes or homemade and vintage items.

It is important to note that the primary thought of users of these kinds of sites is their profits, but their actions are also benefitting the environment as their unwanted products are finding new homes rather than ending up on landfills. While the average person will not associate second-hand markets with the environment, they can make a big impact on the environment. People do not use these sites out of their affinity towards saving the environment; they do it for themselves, and that is a major key for those looking to entice their target market with CE.

An example of a retail business which has adopted a circular business model in transforming their approach to business is GameStop. According to Ellen MacArthur Foundation (2017c), GameStop has transformed from a software and video games retailer into a leading proponent of the 'highly developed buy, sell, trade' programme. This initiative involves the creation of value for clients through the recycling and refurbishment of game consoles and associated items like Android and iOS devices which are no longer in use.

These products are reverse-engineered in a refurbishment operations factory in a most cost-effective manner, and to the highest quality standards possible, without any input from the original equipment manufacturers. The refurbished products are sold in the open market at reduced prices. However, there is growing apprehension about the effect that increasing the desire of consumers for new game consoles and online gaming experiences will have on the viability of the physical game interface (Hollister, 2012).

Mazuma mobile is another example of an electronics retail business that has given verve to the CE tenets in strengthening the value proposition of its business. According to the company's website, it describes itself as a pioneer in mobile phones recycling and reuse (Mazuma, 2018). The business was set up to cater for a need to recycle and reuse an estimated 50 million unused and/or disused handsets available in the UK market. The progenitors of the business ascribe a loss in value of £5 per month (a cumulative loss of about £3 billion) to these handsets if they end up in landfills and thereby advocate for a resort to recycling and reuse.

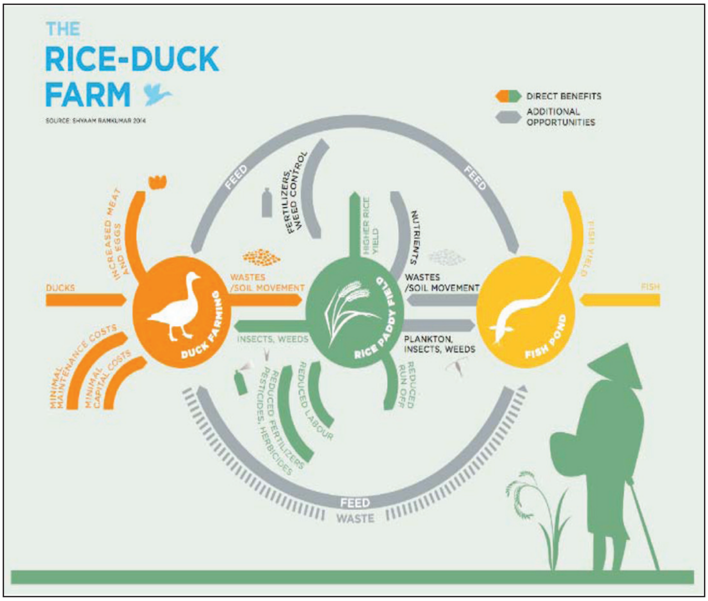
Other entities within the fast-moving consumer goods (FMCG) sector have leveraged on industrial symbiosis to enhance profitability and productivity levels. One of such entities is Taka Furuno. Taka Furuno's evolution was predicated on the persistence of diminishing margins on agricultural goods which implied that engagement with large-scale production is imperative for the attainment of sustainable living conditions. Yet, most farmers can only engage with subsistence farming, thus negating their ability to earn a living from agriculture. As such, Taka Furuno's emergence was based on the need to deploy the principles of highest and best use to the available land through industrial symbiosis tenets. This resulted in the expansion of farm produce variety and an elimination of agricultural inputs.

According to Ellen MacArthur foundation (2017d), a Takao Furuno farm is modelled to thrive on a complex multi-species farming arrangement (see Figure 4).

Under this arrangement, there is emphasis on the overt reliance on multiple species in a manner that suggests complete independence from external farm inputs to produce a wide variety of farm products. In this wise, rice seedlings are

FIGURE 4

The Takao Furuno Business Model



Source: Ellen MacArthur Foundation (2017d).

introduced into an area replete with flooded rice paddies prior to introducing a raft of ducklings. The rice seedlings attract insects that feed on them and, consequently, these insects serve as food for the ducklings therein. A range of easily cultivated fish species referred to as loaches are introduced at this stage alongside a water fern—termed paddy weed. This weed serves to fix nitrogen in the air—a natural substitute for artificial fertilisers—thereby enabling a healthy growth of the rice seedlings. Yet, the weed's growth is controlled by a combination of the ducks and the loaches who feed on them. Also, the ducks and loaches, through their droppings, provide certain nutrients which are deemed imperative for the survival of the rice seedlings. The weeding prowess of ducks is known as farmers have been reported to use them to avoid the sourcing of about 240 man-hours per hectare in manual weeding per annum (Ellen MacArthur Foundation, 2017d). The ducks are moved from the rice paddies when the rice seedlings have grown ears of grain to another part of the farm. This move is necessitated by a need to ensure that the ducks do not eat the ears of grain. Rather, they are fed with surplus rice grain in their new location. Obviously, this system is regenerative and highly productive as it yields a variety of farm products, namely, rice, fish (loaches), feed and ducks, which can be sold to generate more income.

Evidence shows that yields from such farms exceed the yields from conventional industrial rice farms by 20–50 per cent, thus allowing the farmer to compete

Figure 5

Pneumatic Waste Conveyance Systems (PWCS)

Source: HBD (2015).

favourably with large-scale farmers through competitive pricing regimes (at a 20–30% premium over the latter) (Ellen MacArthur Foundation, 2017d).

Transportation

Shared transportation is another good example of CE via shared use or consumption. Uber is an example of automotive transportation. Bike-sharing companies around the world such as Ofo, MoBike, Anywheel and SG Bike are examples of urban convenience travel by means of electric bicycles connected by information technology. They unlock the unused value or idle value of products. Business value is built on services and not the products.

Uber was founded in San Francisco in 2009 by the duo of Travis Kalanick and Garret Camp as a disruptive enterprise to alter the status quo ante of the taxi industry. By 2015, when the entity had turned 5, it had become a global network, with a presence in 311 cities in 58 countries. It has been referred to as the face of the sharing economy concept in the transportation industry. Prior to the emergence of Uber, on average, a personal car is unused 92% of the time. The idle time of cars is a significant resource for sharing economy transport solutions and an opportunity for CE. The impact of the sharing economy, as epitomised by Uber in the transportation sector, on jobs has been reported. Far from the fears being expressed concerning the potential of Uber to displace drivers in the traditional taxi industry, its introduction led to a decline in the hourly earnings of wage-employed drivers, a difference which was duly compensated for by increments in self-employed drivers' incomes (Berger et al., 2017). Yet, Berger et al. (2017) discovered that the model had no negative impact on employment within the taxi sector whilst yielding to higher capacity utilisation by drivers within the Uber sphere. This is supportive of the value creation agenda buttressed by the sharing economy philosophy—an integral aspect of CE.

Circular Economy Frameworks in South Africa and Singapore

Circular Economy Policy Framework in South Africa

The global trend towards CE shows that the waste sector is currently undergoing a paradigmatic shift from an end-of-pipe treatment of 'waste' to one recognising that waste is a valuable 'secondary resource' that can be recovered and reintroduced back into the economy (DST, 2014).

The environmental, social and economic benefits of waste minimisation and diversion away from landfill towards value-adding opportunities has gained increasing local and global attention. This shift is being driven by developmental issues like population growth and urbanisation, growing consumerism, increasing quantities and complexity of waste, climate change, carbon economics, resource scarcity, commodity prices, energy access, food security, globalisation, unemployment and tightening regulation. Consequently, the strategic importance of the sector is spelt out across several sustainable development goals.

Waste management is now part of a global economy, which has both positive and negative impacts on a local waste sector, including increasing exports (loss) of secondary resources. The growing demand for resources globally is driving flows of recyclables to countries with market opportunities (demand), and unless local markets are stimulated, secondary resources will increasingly flow out of local markets of developing countries to established international markets. However, growing local markets, and managing investment and technology risks, is dependent upon increased access to recyclables (quantity and quality).

The result of this paradigm shift from 'waste' to 'secondary resource' requires a 'change in the governance of waste from protection to re-use' (Oelofse & Godfrey, 2008, p. 245). South Africa has adopted a largely conservative, protection-based legal definition of waste, which is often seen as an obstacle to waste recycling and recovery, as opposed to a more supportive 'resource-based' definition. Furthermore, South Africa has seen considerable waste policy development over the past 5 years, since the promulgation of the National Environmental Management: Waste Act (Republic of South Africa [RSA], 2009) and the National Waste Management Strategy (NWMS) (DEA, 2011). While the Waste Sector Survey (DST, 2013) has shown that a supportive policy framework has the potential to stimulate sector development, growth and innovation, if over-regulated, it can hinder or slow innovation. The goal for South Africa must therefore be to find a balance between 'encouraging' and 'controlling' within a waste policy framework.

The national Waste Baseline study shows that South Africa generated ±108.5 MT of waste in 2011, of which 97.8 MT (90.2%) was disposed off to landfill (DEA, 2011). With only 9.8 per cent of waste being diverted from landfill (as at 2011), the dominant technology for South Africa remains landfilling, often to open and uncontrolled dumpsites. The past 2–3 years have seen the introduction of some alternative waste treatment technologies, including mechanical and biological treatment; however, widespread adoption of technologies remains limited. As such, large volumes of potentially recyclable materials are currently being lost to the economy and, with it, new jobs.

A key question facing South Africa is how to integrate the informal sector into the local waste and secondary resources economy, in light of the opportunities that exist and the need to create new and decent jobs, and the impending extended producer responsibility schemes for paper and packaging, WEEE and lighting (Godfrey et al., 2016).

Although the waste hierarchy has been embedded in national policy since the White Paper on Integrated Pollution and Waste Management (RSA, 2009), it is has become essential for government to create a safe, stable and conducive environment for waste prevention, reuse, recycling and recovery businesses to grow and prosper.

Circular Economy Policy Framework in Singapore

Singapore has indicated its desire to assume the status of a zero-waste nation. This appears to be an ambitious target, considering that the nation generated waste in excess of 7.7 million tonnes, a sevenfold increase from 40 years ago (Zero Waste Nation, 2019). According to information available on the website ZeroWasteNation.com, Singapore faces the risk of having the only landfill site—the Semakau Landfill—run out of space.

An overview of the waste management system in Singapore indicates that 37 per cent of the generated waste is incinerated, whereas 67 per cent is recycled, and a further 3 per cent is sent to the landfill (NEA, 2018). This reality has accentuated the need for proactive measures to combat the impending waste crisis in the country. The transition towards CE appears to be a natural choice for a country with a comparatively small geographical landmass (722.5 km^2). Ranked 176th in terms of geographical area, the country cannot sustain the allocation of large swaths of land for landfilling purposes in the face of an increasing population and demand for land for alternative uses.

As such, Singapore has initiated different approaches towards achieving the zero-waste nation status through the provision of a loop system which closes out the waste and extends the producer responsibility in most parts. These approaches include:

1. Provision of adequate infrastructure to cater to recycling needs of the occupants of Housing and Development Board (HBD) flats and private residential developments in excess of four storeys.

2. The provision of Pneumatic Waste Conveyance Systems (PWCS) in HBD flats. According to the HBD, the PWCS is an automated system for waste collection being trialled in HBD flats in Singapore. This system of waste collection is predicated on the presence of a vacuum-type underground network of pipes. These pipes collect household waste and transport the waste to a sealed container via underground pipes for onward collection by trucks. This approach eliminates the environmental and sanitary issues associated with open refuse collection. Other benefits of the PWCS system include the reduction in manpower hours expended on household waste collection and its utility in engendering the separation of waste for recycling (HBD, 2015). The Integrated Waste Management Facility (IWMF) is another strategic initiative being introduced to achieve the zero-waste nation status. According to NEA (2018), it is expected that the facility, when it comes onstream in 2021/2022, will provide an integrated platform for the treatment of solid waste from a coterie of sources like incinerable waste, household recyclables, source-segregated food waste and dewatered sludge, all collected under the auspices of the National Recycling Programme (NRP) and the Tuas Water Reclamation Plant (TWRP). The innovative strides associated with this project include energy recovery maximisation, reduction of environmental impact, future proofing of the facility to allow for easy disassembly during renewal process and upgrading with new technologies, for example.
3. The mandatory reporting of packaging data and packaging waste reduction plans is another innovative approach introduced to curb the incidence of waste in Singapore. This initiative is expected to start in 2020.
4. Finally, the introduction of the extended producer responsibility framework for e-waste management by 2021 is expected to foster the design of products for CE and encourage urban mining through environmentally friendly processes.

These strategies indicate that Singapore's transition to a zero-waste nation status is on course through the instrumentality of 4IR technologies and the CE concept.

Facilitating Circular Economy Transitions Through Universities in the Fourth Industrial Revolution

Universities emphasise their role in shaping future technology advances by serving as innovation test beds for educating future generations. Traditional education has contributed greatly to the current levels of industrial evolution and technological advancement. However, for higher education to deliver future generations with the right set of skills and knowledge to contribute effectively in the 4IR or industry 4.0, the delivery of education should transform to combine the strength of the traditional higher education with digital innovations. Additionally, the education should impart global competencies and deliver customised and individualised student experiences.

CE-led thinking can lead to innovative ways of doing things, contribute to new research ideas and highlight collaboration opportunities. Its integration into an organisation's operations can result in financial savings from optimal use of resources and bring benefits for society and the environment. For staff and students, it can contribute to the development of new ways of thinking and tackling global challenges in a resource-constrained world. There are several opportunities for a university to differentiate itself as forward-thinking and exemplar in relation to CE.

Fostering 4IR + CE in the South African University Landscape: The Case of CUT

Universities within the South African higher education landscape appear to be picking up the gauntlet as pertains to the transition towards a 4IR technology-enabled CE era. This is especially the case when compared to their peers in sub-Saharan Africa. Initiatives around this theme consist of efforts which are embedded within teaching and learning, research and community/industry engagement, as well as university operations.

For instance, steps are being taken at the Central University of Technology (CUT) to engender a strategic transformation towards a 4IR + CE era. In this regard, a taskforce was recently set up to drive this transition in a whole-of-campus manner.

A plethora of projects set up in accordance with this strategic objective includes the following:

1. *The e-waste plant*: This initiative was set up on campus as a collaborative arrangement between CUT and external partners to engage in the recycling of electronic waste. It is expected that this pilot project will provide a platform for developing and strengthening the skills of members of the local community to enable them to engage in the e-waste recycling process in a beneficial manner.
2. *The SMART campus/city initiative*: Leveraging on the availability of 4IR technologies such as IoT and associated skillsets, CUT has commenced moves to support the host city's SMART city aspirations. However, there is consensus among key players in the institution on the need to use the CUT environment as a test bed to strengthen the case for such a transition on a city-wide basis. By implication, successful transition to a SMART campus status by the CUT will provide the value proposition for the city to make the same move. As such, CUT has initiated the transition to a SMART campus status. Different projects are currently ongoing in this regard. First, the SMART Farm initiative was conceived with the intention of bringing about improved efficiencies in the agro-allied sector. The introduction of 4IR technologies in this will lead to a reduction of waste and encourage better decision-making as concerns what to plant and how to plant to get effective yields. Also, it provides the opportunity for land to be deployed to its highest and best use. Second, the SMART Bin initiative has just commenced with the

procurement of waste bins. These bins, which are fitted with proximity and moisture sensors, are strategically located within the campus. These sensors are linked to a web interface and a specially developed mobile phone app to keep facility management staff abreast of the status of the bins, that is, when they are full or when the contents become damp, for evacuation. Also, plans are in place to ensure that the contents of these bins are sorted according to the nature of the waste and weighed prior to subsequent recycling or reuse. This will facilitate not only effective reporting of the amount of waste that the institution is generating but also the determination of the percentage of that waste prevented from being landfilled.

Another project which happens to fall under the SMART city/campus flagship is the SMART building project. This project is concerned with engendering an improved degree of resource efficiency in existing university buildings whilst ensuring that the future buildings are designed for SMARTness. Of interest in the case of the buildings is the attainment of improved efficiencies in energy, water and space utilisation. Aligned to this project is the dynamic timetabling system through which CUT seeks to ensure that the lecture theatres are booked in accordance to the number of prospective attendees to reduce wastage. Finally, the paperless regime is another initiative through which the institution seeks to curtail the use of paper. The digitisation of official records is ongoing to sustain the culture of a paper-free work environment. Printing has also been centralised to ensure that staff adhere to the mandate of this initiative.

3. *CE-driven procurement*: CUT has focused on the adoption of most of the circularity strategies as explicated by Potting et al. (2017). The decision to re-use, repair and refurbish has been prioritised over the decision to procure new service delivery platforms. For instance, some buildings which have hitherto been deemed redundant and in a state of disrepair are now being renovated to provide service to the institution.
4. *Teaching and learning and research*: Finally, the university is in the process of developing modules for staff and fresh intakes (first-year students) to sensitise them on the utility of 4IR technologies and the role of these technologies in facilitating advancements in CE at the institution. Also, the research centres at the institution are being encouraged to undertake research from a multi-, inter- and trans-disciplinary (MIT) perspective to foster the development of new knowledge as pertains to 4IR, CE and the broader sustainable development theme. Within the teaching and learning realm, available 4IR technologies are being deployed as teaching and learning platforms to facilitate learning and expose students to the utility of such technologies.

The projects highlighted indicate the operationalisation of the CE-driven transition, which is ongoing at CUT. Also, the criticality of 4IR technologies in bringing this aspiration to fruition can be deduced from the nature of the projects being embarked on.

Conclusions

Moving towards CE can be daunting. Yet, by adopting CE principles, more and more companies are gaining real competitive advantages: getting ahead of rivals by innovating for both resource efficiency and customer value and creating change at the intersection of the company's strategy, technology and operations.

In the face of runaway resource scarcity and rising customer and policy expectations for better, more sustainable products, there has never been a better time to start. By developing a proactive strategy—built on a clear understanding of the motivation to leave behind the linear model and underpinned by the business models, technologies and capabilities critical to success—companies can create superior value and capture circular advantage.

Higher education institutions can and should play a pivotal role in the transformation of local, national and global economies. They should play a pivotal role in transforming the linear economy to a CE. They can supply the market with cutting edge research that promotes the adoption of CE initiatives and can also study and analyse the concept from a theoretical perspective. Universities educate designers, engineers, business leaders, procurement decision-makers, potential market influencers, policymakers, social leaders and many others. In addition, they have the leverage to influence supply chains as well as persuade diverse stakeholders including governments, political bodies, future generations and the public.

It is an opportune time for universities to further collaborative works, both within respective institutions and with external partners, in emerging industrial revolution, which is a symbiosis of industry 4.0 and CE, as universities should play a pivotal role in transforming the linear economy to a CE.

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