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Abstract

The origins of the Linear Economy – the 'take-make-use-dispose' model of consumption – date from the Industrial Revolution and the global economy developed around this model. Various social, economic and environmental factors mean that it is no longer sustainable. A radical new model – the Circular Economy – is being advocated but as yet it is not widely practiced. This paper proposes that designers are crucial to the development of this new economic model; furthermore, this model facilitates education *for* sustainability and enhances employability.

Keywords

circular economy, education for sustainability, sustainable design and manufacture

Introduction

The origins of the Linear Economy – the 'take-make-use-dispose' model of consumption – date from the Industrial Revolution. This paper first considers how the global economy developed around this model and the role of designers in its development and perpetuation. It then considers some of the factors that demonstrate that the Linear model of production and consumption is unsustainable, as a consequence of which an alternative model – The Circular Economy, which mirrors natural life cycles – is being advocated. Some of the various economic, social and environmental factors that are changing perception of the Circular Economy as a 'well-intended' marginal model to a viable and essential alternative to current and predominant Linear practice are then considered. In order for this to happen, however, a number of barriers and constraints must be overcome, examples of which are briefly discussed. Just as designers facilitated the development of the Linear Economy, the paper proposes that they have the potential to facilitate and even lead the development of a Circular Economy. Not all designers are sustainability literate, however, and some are reluctant to engage with sustainable design. This

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paper then concludes that changes in design thinking and practice should occur if Education for Sustainable Development is thoroughly embedded in design curricula; not all students will want to engage with sustainability issues, however, but by learning about the Circular Economy, the various factors that contribute to this model mean that education for sustainability will be implicit.

Industrial revolution, technological development and economic growth

In 1776 the economist Adam Smith stated that, in addition to agriculture, gold and silver, the 'wealth of nations' was grounded in 'national production', i.e. manufacture (Smith, 2012). The quantity, variety and speed of production increased concurrently throughout the first and second Industrial Revolutions, which were due in part to mechanisation, the development of new energy systems and materials and to the division of labour (which increased efficiency). Production processes were further accelerated during the 1950s following the invention of industrial robots and CAD CAM (Computer Aided Design and Computer Aided Manufacturing), since when utilisation has become widespread. Digital manufacture has further evolved and is now facilitating emergence of the Third Industrial Revolution that includes additive manufacturing (3D printing) and a shift from centralised to decentralised local and domestic manufacture.

'National production' was critical to and developed as a result of the demand–supply–income cycle (Goossens et al., 2007), and, as predicted by Smith national and personal wealth increased. In the UK, for example, between 1700 and 1871 Gross Domestic Product (GDP) increased 53% per capita between (Broadberry et al., 2011) and an even greater increase in GDP of 400% per capita was recorded between 1900 and 2000 (Hicks and Allen, 1999).

The first industrial designers

Until the late 19th century products and services were 'designed' by artists, architects, engineers, trades and craftspeople because the design profession as such did not exist. The development of design associated with new technologies, manufacturing processes and industries required new thinking however. One of the first exponents was Christopher Dresser who championed design reform in the UK from the 1860s; he designed aesthetically pleasing, functional objects and is renowned as one of the first independent industrial designers. Other individuals also began to design for industrial and mass production including Peter Behrens in Germany who epitomised the new approach when he stated that 'we refuse to duplicate handmade works, historical style forms and other materials for production' (Hauffe, 1998). These and other designers democratised design and made new products and types of product accessible to the growing middle class which in turn fostered the demand–supply–income cycle as manufacturers recognised the value of design to encourage sales.

Planned Obsolescence: Key issue for sustainability

Prior to and following World War I wealth and income increased concurrently as new markets developed for novel inventions and services such as the telephone, motor car, electric lighting and domestic appliances. The apparently self-perpetuating demand–supply–income cycle was disrupted, however, by the 1929 Wall Street and later global financial crash and consequently in 1932 Planned Obsolescence was proposed as a means of stimulating the market and ending the Great Depression (London, 1932). The intent of Planned Obsolescence is that consumer goods rapidly become obsolete and are replaced; obsolescence may be perceived or actual and designers and engineers were employed to develop goods that met these criteria. For example, General Motors fostered 'the desire to own something a little newer and a little better, a little sooner than necessary' (Stevens, 2005) by introducing frequent and cosmetic changes (such as new colour or body trim) to their car designs. Similarly the Phoebus Cartel (comprised of Osram, Philips and General Electric) reduced the working life of light bulbs from 2500 to 1000 hours by replacing durable with less durable materials while nylon stockings were actually designed to fail by laddering. Planned Obsolescence certainly increased company profits but over 50 years ago it was recognised as 'the systematic attempt of business to make us wasteful, debt-ridden, permanently discontented individuals' (Packard, 1960). Nevertheless, it is still practiced and is particularly common in electronic products. In many instances, adhesives are used to join components, a positive feature of which is that products can be very slim; conversely use of adhesives makes disassembly difficult without damage to components and therefore repair or replacement of components is difficult or impossible; repair and replacement are also made impossible by limiting or discontinuing supply of spare parts.

The Linear Economy and 'waste': An unsustainable practice

During periods of affluence and abundance such as those during the 1920s and from the mid-1950s Planned Obsolescence encouraged and enhanced the Linear Economy, the take-make-use-dispose model in which products become waste at end of life. In 'developed' countries more affluent members of society simply disposed of unwanted goods although less affluent people repaired and reused goods. The practices of making do and mending (reusing and repairing) and salvaging (recycling) were commonplace across society during and immediately after World War II, because resources were rationed and many were only available for the so-called war effort. Once rationing ended, however, products were again disposed of at end of life. The Linear model was further substantiated in the 1960s when significant changes in global markets meant that salvaging metals, paper, glass and textiles, for example, became less economically attractive than buying new; consequently, as described earlier, products were not designed for disassembly. The Linear model benefitted the creative, manufacturing and retail industries, energy suppliers and raw materials producers (such as the mining and oil industries); conversely, however the environment was damaged as vast quantities of waste were sent to landfill sites and/or combusted as waste.

Like consumption, waste is a function of affluence and although it is impossible to quantify how much commercial and/or municipal waste has been produced as part of the Linear Economy to date, it is predicted that the quantity will rise concurrently with population growth, rising income and behaviour associated with urbanisation. Urbanisation is expected to account for 70% of global population by 2050 and urban residents generate twice as much waste as their rural counterparts. Currently, the global population produces about 1.3 billion tonnes municipal solid waste per year but this could increase to 2.2 billion tonnes per year by 2025 (World Bank, 2012). Disposal at end of life has never been a sustainable practice but a number of factors mean that it is becoming increasingly unsustainable. These are now discussed in brief and highlight the need for an alternative to the Linear Economy.

Resource demand and the impact of risk to supply

Population growth and increasing GDP

Although levels of happiness and life satisfaction have not increased concurrently with GDP (Goossens et al., 2007), increased wealth has enabled significant developments in scientific and medical knowledge and technology that, in conjunction with improved diet, have reduced child mortality and increased life expectancy. Consequently, global population rose from approximately one billion in 1804 to 7.2 billion in 2014 and a further increase to 9.6 billion by 2050 is anticipated (UN, 2012). Such a dramatic growth in population, purchasing power and consumption are already having an unprecedented impact on demand for many resources and more metals, minerals and fossil fuels were consumed during the 20th century than in all other centuries together; moreover demand is expected to increase.

The risk to resource supply: Minerals

This growing demand could threaten supply in the future, however, because natural resources such as minerals are finite and many reserves are already very limited. In addition to abundance, other threats to supply are becoming increasingly apparent, examples of which include political instability, bribery and corruption, land grabbing and ring fencing of reserves (British Geological Society, 2012). The impact of restricted supply differs from resource to resource but typically they influence economic viability and in extreme cases whether a product can be manufactured or not. Supply can also affect health and well-being if minerals are extracted and processed without proper care for the environment and workers while the sale of ‘conflict minerals’ can be used to fund arms and war. The desire to control resources has already caused wars (as in the case of oil and the first Gulf War) and it is possible that the control of water supply will lead to conflicts in the future.

Water, energy and associated emissions

Water can be embodied in materials and/or operational; like other resources, an increase of 28% in demand by 2025 is forecast (Rosegrant and Cai, 2002). Water differs from other resources, however, because it is essential to life but clean and secure supplies are already threatened by industry-related pollution, naturally occurring disease, economics and politics. Although pollution can be avoided through proper management, it is more difficult to fairly manage up and down-stream supply as various countries want access to this same supply at differing points; this could cause conflict in the future as demand rises.

Like the demand for raw materials and water, energy demand is also increasing exponentially despite the fact that products are becoming progressively energy efficient. The number of products being used and manufactured is continually rising and, in addition to operational energy they embody energy (for materials extraction, processing and manufacture). It is no surprise therefore that individual primary energy consumption per year rose 800% between 1850 and 2010 and it is expected that demand will increase by a further 56% in 2040 (EIA, 2013).

In addition to various damaging emissions to water, emissions to soil and air also derive from energy generation, manufacturing and other industrial processes. These are directly impacting on global climate, weather patterns and ecosystems, the subsequent impacts of which include drought and flooding, damage to health and well-being, life expectancy, crop failure, mass migration, people trafficking (IPCC, 2014).

In summary

Despite the innumerable positive outcomes for millions of people that derived from technological, medical and other advances since the first Industrial Revolution, the information above clearly shows that the Linear Economy is unsustainable and that there is an urgent need for an alternative model. The article now proposes that the Circular Economy – which is described in detail below – be developed.

Biomimicry and the Circular Economy

Humans have been observing and learning from the natural world for millennia but it wasn't until the late 1990s that the term Biomimicry was used outside scientific circles to describe 'innovation inspired by nature'; it is further defined as 'an approach to innovation that seeks sustainable solutions to human challenges by emulating nature's time-tested patterns and strategies'. The methodology can be applied to problems at any scale: for example, pesticide-free agriculture employs a solution based on natural planting systems found on prairies, adhesive products are inspired by burrs and geckos' feet, hydrophobic nano-surfaces by lotus leaves (that repel water) and natural building ventilation systems by the structure of termite colonies (Benyus, 2002).

A further example of biomimicry is the Circular Economy; this mirrors natural life cycles where dead organic material decomposes to become a nutrient for the next generation of living organisms. Typical examples are leaf litter in forests, which is a nutrient for new plants and for the animals, fungi and microorganisms that carry out the decomposition process – and dead animals that become food for scavengers ranging in size from microorganisms to fly larvae, birds and mammals. In all cases the dead material is vital to the food network that is, like other natural systems, highly efficient and does not create waste. One example of a Circular Economy could include food waste, natural yarns, wood products and biopolymers will create 'biological nutrients' (compost) while another could include non-organic materials such as polymers (plastics) and electronics materials that become 'technical nutrients' for the next generation of products. This concept was initially introduced during the 1970s by the Swiss architect and economist Walter Stahel who proposed that materials be processed in a 'closed loop' and 'waste' becomes a resource. Stahel defined this as a 'Cradle-to-Cradle' system and the Linear model as Cradle-to-Grave (Stahel and Giarini, 1989); he also identified the need to extend product life through repair and remanufacture (Stahel, 1981), which are also now seen as integral to the Circular Economy. Cradle to Cradle is also a design method employed by William McDonough (architect) and the Michael Braungart (environmental chemist) who state that it will facilitate 'design for abundance' (McDonough and Braungart, 2002) and as a consequence of which they developed the C2C benchmark to endorse and promote products that meet this standard. Dematerialisation (reducing material input while maintaining performance) and alternative business models such as leasing and service provision (which includes maintenance for example) are also integral to the Circular Economy.

A typical product life cycle is comprised of four key stages: raw materials extraction and processing, manufacture; use and end of life. It has already been explained that, in the Linear Economy, at end-of-life materials are treated as waste and are either sent to landfill or incinerated. In addition to using land that could be used for housing or agriculture, emissions, toxins and other pollutants can be produced during decomposition. Conversely the

Circular Economy reduces risk to supply by keeping materials in circulation and even though energy and resources will still be required for disassembly and recycling, by eliminating the initial life cycle stage (extracting and processing bulk materials) it also reduces the quantity of spoil, up to 75% of embodied energy, embodied water, associated emissions, environmental and other impacts.

Extended product life, buying a service (such as the replacement of physical CDs with the MP3 format and music service, e-books and readers) and leasing also contribute to the Circular Economy and are advantageous because the manufacturer has control over the products which can be easily maintained, repaired and upgraded throughout life. Furthermore at end-of-life suppliers have control over reprocessing and recycling and can manage the output in open or closed materials loops (where materials are made into different or the same products). In addition to reducing risk to supply of resources, the Circular Economy also has the potential to reduce corrupt and unethical practice; this will foster Sustainable Development because it will be much easier to carry out accurate supply chain audits and to either select ethical suppliers and/or to encourage unethical suppliers to change their practice.

Some major producers (e.g. Caterpillar, Philips and Rolls Royce) and some smaller producers (e.g. The Bond Group (who produce commercial refrigeration equipment) and Closed Loop (who recycle and remanufacture plastic bottles)) are developing alternative business practice en route to a Circular Economy; however, the significant majority of businesses are not. This is partly due to lack of knowledge and understanding of the concept and because it represents such a dramatic change of practice. Some concerns and barriers are practical (e.g. the network and/or supply chain for disassembled products and components and recycled materials is not yet established) while other barriers are perceptual (there is a common belief that remanufactured, reengineered parts and recycled materials are inferior to virgin materials). Furthermore at present the majority of products in circulation were not designed to be disassembled or recycled and consequently the process of doing so can damage components and materials while the cost and complexity of disassembly is relatively high. These and other constraints are being challenged by some governmental and non-governmental bodies examples of which include APSRG (the All-Party Parliamentary Sustainable Resource Group), Innovate UK, the Ellen MacArthur Foundation and Royal Society of Arts' Great Recovery project which all promote and support research into the benefits of and business opportunities associated with aspects of the Circular Economy. Encouraged by this research, in October 2014 the EU Commission proposed that legislation be introduced as a driver to create a zero waste circular economy across Europe; in December 2014, however, this was questioned by various neo-liberal economists and industrialists who are concerned that there could be a negative impact on free trade (European Commission, 2014). Consequently, the extent and future introduction of European and/or UK legislation is currently unknown.

The Circular Economy concept was initially proposed outside government and to date it has been driven predominantly by academics, NGOs and private business. Despite the aforementioned political factors, over 90 non-governmental stakeholders including retailers have joined The Circular Economy 100, a scheme to share best practice and develop a Circular Economy. One major retailer is the Kingfisher Group/B&Q (DIY and garden products) who state that they are able to carefully manage the design of their own brand products and ensure that they can be easily recycled. They also state that it is difficult to influence the design and recyclability of other branded products which further emphasises the necessity for designers to design for the Circular Economy, the history and details of which are now described.

Radical design thinkers

Although the concept of the Circular Economy as a business model was introduced in the late 1970s it would be wrong to assume that, following the Great Depression designers only practiced design for the 'developed world' which supported the demand–supply–income cycle. Notable visionary contrarians include Richard Buckminster Fuller and Victor Papanek. Buckminster Fuller advocated efficient design and engineering by 'doing more with less' (which he defined as Ephemeralization) as early as 1938 (Fuller, 1973). More recently characterised as 'lean engineering' and 'dematerialisation' this practice is now relatively common. While Buckminster Fuller was radical he was also accepted by his peers unlike Papanek. Papanek had adopted a radical environmental and ethnographically sensitive approach to design during the 1960s which he documented and discussed in his book Design for the Real World. Here he stated that 'There are professions more harmful than industrial design, but only a few of them' because many designers were responsible for planned obsolescence and had created 'whole species of permanent garbage to clutter up the landscape, and by choosing materials and processes that pollute the air we breathe, designers have become a dangerous breed' (Papanek, 1985). As a consequence Papanek was derided and verbally attacked by his peers who also forced him to resign from their professional body because he criticised them for designing 'shoddy, stylised work that wasted natural resources, aggravated environmental crises and ignored their social and moral responsibilities' (Rawsthorn, 2011).

It could be argued that with foresight and prudence designers could have limited the excesses of the take-make-use-dispose economy had they embraced Victor Papanek's criticism and Stahel's models and changed their practice earlier; while some designers now do so and practice humanitarian, socially and environmentally sensitive design many others still do not. It has already been explained that many products – and electronics in particular – are joined using adhesives and that other practices associated with planned obsolescence are ongoing. For example, Apple use bespoke fixings that are intended to complicate and even prohibit replacement of batteries and other components in their products. Further examples of unsustainable goods include branded printer ink cartridges that are designed to both prevent refilling and use of all ink; similarly printed text books are regularly republished but in new editions page numbers are changed which makes cross referencing with earlier editions difficult.

These practices may be driven by manufacturers or designers; however, designers need to consider the broader and longer term implication of their activities, which again emphasises the need for a change in design thinking and education about and for sustainability, which are now discussed.

Design thinking, the circular economy and education for sustainability

Design Thinking is 'the collaborative process by which the designer's sensibilities and methods are employed to match people's needs with what is technically feasible and a viable business strategy. In short, design thinking converts need into demand' (Brown, 2009). There is evidently a significant and rapidly growing need for a Circular Economy which could be converted into demand if some constraints and barriers can be overcome, the drivers of which could both push change (through legislation) and pull change (through incentives). For example, in order for manufacturers to use recycled materials in their products they need to be confident that the supply of materials will be regular and reliable. This process would be accelerated by the introduction of improved and consistent domestic waste recycling across the UK (and even Europe) where all types of 'waste' are collected by local authorities and private contractors. Initially this would be driven by legislation and supported by a clearly communicated easy-to-follow universal system that encourages residents to recycle everything; growth in the materials stream will subsequently create business opportunities for reprocessing as a result of which the infrastructure for recycled materials will evolve. It has already be explained that many products were not designed for disassembly, and that reprocessing can be relatively uneconomical; in this case special incentives (such as tax relief) should be introduced to develop reprocessing at scale in order to establish materials' loops and maintain economic stability.

Designers cannot wait for the development of a remanufacturing, reuse and/or recycling infrastructure and other alternative business models, however, before they start to design for the Circular Economy; they must anticipate and prepare for the alternative economy particularly where there is a long product lead time from initial concept to shop floor. Designers now have the opportunity to lead the paradigm shift and in addition to designing for the 'closed loop' they have the potential to influence business and consumer behaviour and consumption by extending actual product life and increasing perceived value of products. In order for this to happen, however, some designers need to change their practice while others need to change their practice and thinking.

At present knowledge of sustainable design (which should include design for a Circular Economy) is not mandatory within the profession. Furthermore, this practice is seen by many established designers as an additional (and sometimes inconvenient) criterion to the already long list of factors that are considered as part of the design process and consequently some are unwilling to address sustainability (Andrews and Robbins, 2010). One option is for established designers to gain knowledge and expertise through Continuing Professional Development. It may be difficult to educate all designers about and for sustainability, however, because even though sustainability was recently introduced to the Chartered Society of Designers competence framework as a criterion for membership, it is one of more than 50 minor criteria (CSD, 2008); furthermore, membership is not necessary in order to practice. Sustainable development is also omitted from design education guidelines; for example, the only reference to sustainability in the latest Quality Assurance Agency for Higher Education Subject benchmark statement for Art and Design is a comment about programmes that have broadened their curriculum to include 'professional contextualising subjects' such as 'ecological and sustainable enterprise' (QAA, 2008). A review of these benchmarks is taking place between 2013 and 2015 and it is hoped that, as in the case of comparable professional and education Engineering benchmarks, future Art and Design benchmarks will include sustainability and sustainable development as a principal criteria.

Whether officially recognised or not the importance of education about sustainability cannot be overstated. It must be embedded in design curricula from the first year so that students recognise that these principles should be core to all design activities (Andrews, 2009). Knowledge of and the ability to apply the principles of the Circular Economy must also be embedded in the curriculum so that they also become integral to design practice. Not all students will embrace design for sustainable development but it could be argued that teaching them about the Circular Economy will enable sustainability issues to be addressed implicitly: for example, students will learn to design for longevity (creating products that can be repaired, upgraded and remanufactured, and have a high perceived value) and to design for reduced environmental impact and increased efficiency (via dematerialisation, design for disassembly, closed materials loops and service design). In addition to resource security, students and professionals will also have to address ethical supply in order to meet the demands of potential employers because a growing number are now seeking ethical materials, the supply of which includes fair and equitable trade, safe and healthy working conditions and is free from child labour. Providing that designers have knowledge about and expertise in the Circular Economy they can advise and lead companies to change practice and ultimately benefit from the potential 1 trillion US$ that will be generated by the global Circular Economy (McKinsey and Company, 2012). The Circular Economy will also create employment across all industrial sectors to and from which design graduates and professionals with related expertise will contribute and benefit. Finally, the rapidly evolving industry paradigm of open and democratised innovation in product and systems design and manufacture will also increase student and graduate employment options as they have more opportunity to engage in design-related social enterprises and not-for-profit activities that embody the principles of sustainable development and the Circular Economy.

Conclusion and recommendations

It is evident that even though the first two Industrial Revolutions benefitted millions of people and initiated social, economic and environmental change and development there are many and diverse negative outcomes from the take-make-use-dispose Linear Economy. It also evident that increasing population, wealth, inequity and consumption, demographic change and the demand on resources make this model unsustainable. The role of the designer is to respond to and meet people's needs and develop technically and economically feasible products and services. In the early part of the 20th century in a period of relative abundance, designers achieved this through strategies such as planned obsolescence which created the culture of disposability and met the needs of some but not all people. Designers must now respond to very different social, economic and environmental needs and adopt a holistic approach to problem solving; they must change their design thinking and practice and lead the development of the Circular Economy by creating products and services that match all inherent criteria of this model. A thorough knowledge of this model must therefore be embedded in design courses so that it can be implemented by all graduates in the immediate future. Finally, research has demonstrated that learning *about* sustainability in order to practice sustainable product design can make an impact on the behaviour of students in their personal lives and therefore it can be considered education *for* sustainability (Andrews, 2010). This paper concludes that by learning about and implementing the Circular Economy students and future design professionals will also implicitly be educated for sustainability.

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