CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY – CASE STUDY OF BUILDING PROJECTS

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1.1 INTRODUCTION

In this era of global lack and inadequacies of resources there is need to move away from linear approach (also known as the take –make- use- dispose model) means that materials are sourced, used and at the end disposed as waste. This approach has endured over time due tothe abundance of cheap natural resources. However, alternative means of sourcing and utilizing materials has become very vital due to growing world population and difficulty/expensive nature in accessing resources.

With circular economy, resources usage can be optimized, consumption of raw materials can be reduced, wastes can be recovered by giving it a second life as a new product or recycling. Since construction is a waste intensive is huge. For Cemex Ventures, 95% of their waste are reused, recycled or recovered while only 5% is sent to landfills. Of the 23 million tons of total waste managed, only 0.4 tons went to landfills i:e 1:57ratio.

Cemex opined thus "currently, only 40% of construction waste is recycled or reused in the entire sector with most of it not being used in the creation Of new buildings. With a market valuation of global waste recycling and circular economy estimated at over $ 500 billion USD in 2021, the opportunity to embrace circular economy models is up for grabs and will surely benefit all in the construction value chain both in the short and long- term."

Also the negative externalities associated with the linear approach including increased pressures on landfill, unsustainable levels of water extraction, rising carbon emissions and widespread ecosystem pollution further buttresses the need for alternative means of

Ellen Mac Arthur Foundation (2016) revealed that the economic opportunity of transiting from the linear approach to a circular economy amounts to 1.8trn. However, a cross – industry, cross – performance and multidisciplinary approach is required to realise and capture the benefits of the systematic transition.

Being a major consumer of natural resources, the built environment in order to reduce waste and increase efficiency recognises the importance of fundamentally evolving the processes, components and systems.

Thus, opportunities are created across the gamut of supply chain, example being the fact that some manufacturers are already designing products that could be repurposed or reused.

1.2 FROM LINEAR ECONOMY CIRCULAR ECONOMY

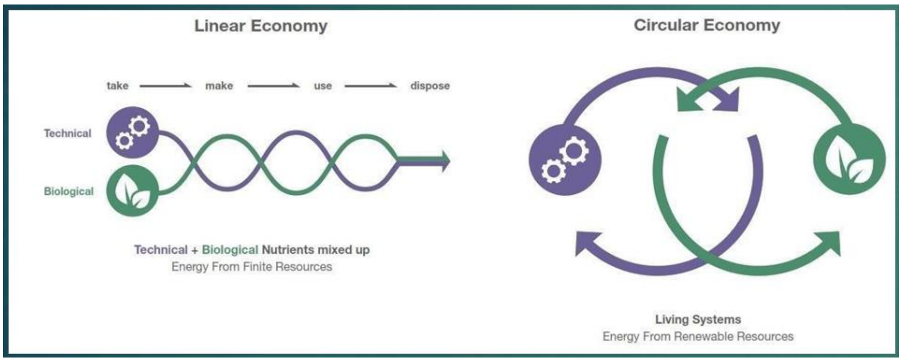


Figure 1: Linear Economy and Circular Economy in the built environment Source: Arup (2016)

According to Arup (2016), the circular economy aims to decouple economic growth from resource consumption. Instead, products and assets are designed and built to be more durable, and to be repaired, refurbished, reused and disassembled.

Components and their materials are thus maintained at the highestuseful purpose as practically feasible so as to minimise resource waste. Circular economy means that natural capital is preserved and enhanced, waste is prevented, renewable resources are optimised while negative externalities are designed out. Furthermore, materials, products and components are maintained at their highest possible intensive value holding them in repetitive loops. Infact the present volatility ofglobal commodities is a pointer to the fact that there is need to reconsider the way society consumes goods.

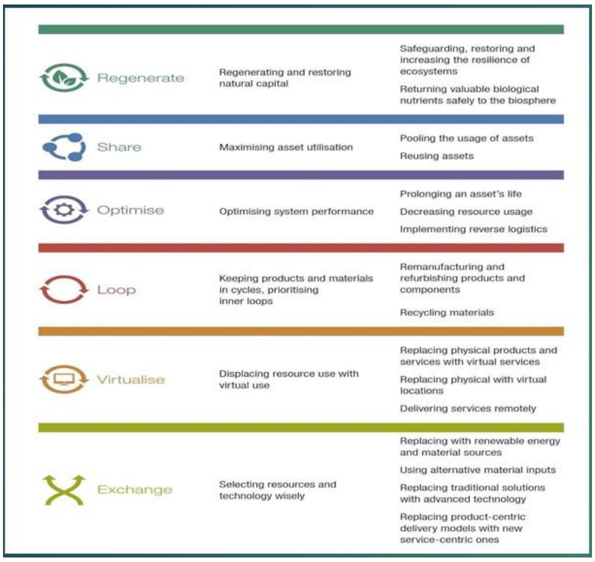
Through circular economy therefore, assets are more fully utilized while diversifying and extending their lifecycles.

1.3 CIRCULAR ECONOMY MINIMISES NEGATIVE EXTERNALITIES

A core aim of the circular economy is the minimisation of negative externalities such as climate change, soil, air, water and noise pollution in the built environment. Also less tangible impacts on human and animal welfare, social equality, health and employment are recorded. Eliminating and/or minimizing these impacts enhances natural capital while the use and value of resources are maximised. This is as theseexternalities can apply to assets operation, sourcing, transportation, manufacture, installation and disassembly.

Figure 2: Negative Externalities such as GHG emissions, air and noise pollution as core aim of the circular economy Source: Arup (2016)

Outlining key principles of the circular economy in the built environment and exploring practical applications that can benefit all parties working in the sector. The Ellen Mac Arthur Foundation's resolve framework (see figure3) is employed in outlining the Circular Economy's Key principles and how each element is applied to show the ensuing benefits.



The Ellen MacArthur Foundations ReSOLVE framework:
Figure 3: A circular Economy Vision Source: Arup (2016)

3. Benefits of Circular Economy

- Less waste generation
- Less landfills dependency
- Less exploitation of natural resources
- Employment creation – according to European Union, 700,000 new jobs would be opened up by year 2030 – Cemex Ventures (2022)
- Reduction of unhealthy environmental impacts – circular economy lowers carbon dioxide emissions.
- Reduction of energy consumption
- Waste management challenge faced by cities and communities worldwide are mitigated.

1.4 Circular Economy in Building Projects and Construction

Cement kilns are used to sustainably and safely dispose non- recyclable wastes, thus using them as fossil fuels alternatives rather than incinerate or landfill them.
In cement production process, fly ash and slag can be used to replace part of the clinker.
Non reusable clinker kiln dust are used in soil or road stabilization, as road de-icing agents during winter and also as fertilizer.

2.0 THE ReSOLVE FRAMEWORK

This framework outlines six actions that guides the transition to a circular economy. They are in the following sequence: i.Regenerate ii.Share iii.Optimise iv.Loop v.Virtualise, and vi.Exchange The above six elements can be applied to buildings, products, cities, neighbourhoods, regions and entire economies. For the purpose of this technical paper, it would be applied to show how circular economy works in the built environment. It should however be noted that for a truly circular economy to be feasible, different scales such as buildings, assets, infrastructure, cities and regions must be integrated into an interdependent and cohesive whole. Therefore, if innovation and cross- sector collaboration are integrated and sealed up, a more complete circular economy is achievable.

2.1 REGENERATE

(i) Natural Capital Regeneration and Restoration Regeneration in the built environment allows for efficient and circular building performance through the reduction of negative externalities, consumption of wastes and primary resources. By this, ecosystems are safeguarded, restored while resilience increased. Low-impact design, materials and operation of assets and buildingsare promoted by net zero strategies. Negative, Social, Environmental and Economic impacts of the built environment including emissions, air pollution, wastes and associated costs are drastically reduced. Through anaerobic digestion, bio-refining and composting, biological resources can be extracted and reused thereby generating energy and cutting emissions. More biological materials are also returned to the soil to replenish it. The reputation of individual companies and the wider industry are enhanced when waste from landfill are diverted, materials and products are used more efficiently and air quality is improved. Cities are equally made more liveable, attractive and cleaner.

(ii) safeguarding, resting and resilience increase of ecosystems Resilience in the built environment ensures that assets and servicesare robust, reliable and adaptable to ongoing stresses and sudden shocks. The choice of materials and designs employed enhances resilience. Opportunities for future reuse, flexibility, redundancy and disassembly are considered. This ability to withstand known andunknown future conditions are taken into account during design of assets. Assets are therefore built for longer lifespans and evolving needs while also lowering the waste and environmental impact of materials used. An example of ecosystems restoration and resilience increase in the built environment in Amps Madrid + Natural Initiative proposed nature-based design solutions so as to regulate the urban environment of Madrid (Arup, 2006). Included in the design are: replicable green infrastructure solutions to resolve challenges of city such as extreme heat events, flooding, loss of bio diversity, water scarcity and reduced access to green spaces. Arup said “employing an incremental approach, small scale interventions were planned to connect with existing larger green roofs and facades would be inter connected”. Temperatures has been reduced up to 4.5oc where strategy has been implemented.

(iii) Valuable biological nutrients are safety returned to the biosphere The return to the biosphere of biological nutrients to the biosphere of anaerobic digestion or composting are included in regeneration. Thisensures bio-chemicals such as biogas, energy and nutrients to be recovered. Other nutrients and valuable by-products could also be generated to create revenue streams and new markets.

Example: - A Circular Economy strategy in Scotland is part of making things last. The horizon proteins method was developed by a team of Heriot-watt University. Underused resources such as barley, wheat and yeast from the brewing and distillery industries are taken to create protein products for fish and animal feed.

In this process protein is recovered from whiskey production by product known as pot-ale. Being a low-cost and low-energy solution, imports and associated environmental costs and impacts are reduced. An additional high-value revenue stream is provided the whiskey industry while the development of a new market for protein productslike salmon feed are supported.

2.2 SHARE

(i) Assets use maximisation

The built environment sector uses infrastructure, vehicles and spaces more efficiently when assets use is optimised. In the car industry peer to peer sharing has come to stay with schemes such as Uber, Bolt, Getaround, BlaBla Car and Zipcar that promote renting and sharing of buildings, construction materials, equipment’s and underused spaces is also well established in the built environmentsector In densely populated cities, co-location, shared and flexible working spaces are becoming increasingly common place. The idea is that when less spaces are occupied and time an asset is idle to minimised, fewer resources are employed to deliver the same service or function. Hereby recording less waste. Examples include sharing facilities and vehicles, making greater use of workplaces and offices within the 24-hour cycle and housing more people within a footprint that is smaller.

The approval of shared ownership and sharing platforms provides further revenue and cost savings for operators and owners. An example is the flexible working for 20% of its office working space with 18,000 staff which enabled the Lloyds Banking Group to remove 1,000 desks and save £10m from its London offices.

Another great example of asset optimization business model is Airbnb whose site allows people to rent out spare rooms in their homes. It now has two million listings across 192 countries and sixty million users with the

organisation valued at about $25bn.
Airbnb guests in US alone in 2014 used 63% less energy than hotel guests. Also water equivalent to 1,110 Olympic sized swimming pools was saved by Airbnb in Europe alone while GHG emissions equivalent t0 220,000 cars were avoided.
(ii). Assets Usage Pooling
Online platforms and apps are used to collect and share real-time data and maximise assets used in sharing economy businesses. A built environment is the open source design platforms like Wikihouse which permits designers users so that they can customise and/or construct buildings themselves.
The adoption of best practices is facilitated by the exchange of information in a standardised format. Thus associated principles like designfor disassembly, modular construction and the use of circular and sustainable materials are consequently adopted. Modification and improvements to designs and software by community maximises the use ofdesigns, increase their lifespans and support across multiple application, thestandardisation of components.
3D Hubs – an online platform for engineers and designers to access underutilized
3D printer capacity in their city now has 32,000 printers in over 150 countries.
Airbnb for off-site meeting spaces allows users organise private parties, rent underutilized spaces for meetings, team-away days, conferences and
workshops. A wide audience is reached by an easy to use online platform.
Costs are cut for conventional event space booking agents while it is very easy for owners of assets to take advantage of under-used space.
(iii) Assets Reuse Economic, Social and Environmental benefits are created by reusing
materials/components through redistribution or resale. Also, greater
collaboration is engendered between asset owners, operators, platform developers, industry partners and technology companies and more often resulting in resource use reduction, costs cutting, increase in trust among users and technical innovations.
In order to create value for all more disparate elements of the built environment
supply chain have to collaborate to scale up circular economy practices.
Businesses, individuals and clarities who desire to acquire or give away surplus or unwanted stock and equipment in the construction office and retail sectors are matched by Globechain – a reuse platform.
Through gathering and analysing data, Globechain evaluates the economic, environmental and social impacts of the exchanges thereby enabling businesses to assess and report on the effects of recycling, upcycling and renting items. About $3,000 in landfill charges, about
$3,000 – $4,000 on the cost of new furniture and living cost were saved when Telefonica used Globechain to pass on unwanted office furnitureto the charity growing networks.

2.3 OPTIMISE
(i) System performance optimization
Assets, products and system operating at maximum efficiency and performance are optimized. In the build environment, optimization is achieved mainly by maintaining components and materials at their value plus employment of design and instruction eliminate waste.
While flexible design methodologies and digital technologies and optimization of assets performance, modular components and off site. The elimination of primary materials use is achieved through reuseof components and materials in contacting new buildings either transferred for use in other sector or repurposing for use in infrastructure.
(ii) Assets life prolongation
Long – term Durability, utilization and value of assets are achieved through designing for longevity.
Reducing maintenance costs and extending the economic viability structure are achieved by employing durable materials and robust combination standards. Minimization of source of structural faults and reduction of long – term maintenance can be achieved through off – site manufacture of standardized components to higher quality standards To ensure that assets are used optimally throughout their lifecyclesand reduce waste, designs, should be done for longer life spans. Designing for flexible building cores, assets are enabled to switch use later on – from commercial to residential.
In the Derwent London's White Collar Factory in old street, London, there are commercial, residential and public spaces with exposed services, adaptable floor plates and internal fittings to enhance every subdivision, flexibility and interactivity over time. The buildings lifespanis prolonged by these elements.
i. Resources Usage Decrease
Principles such as modular components and off-sites construction in the built environment reduce the amount of waste produced on-site, enable repurposing and refuse. From the start, waste can be designed out. Circular resources and materials flows between industries, sites and assets are made possible by demolition and

i. Implementing reverse logistics
This is a closed crop approach which uses repairs, recycling or refuse, refurbishment and remanufacturing for recovering and processing materials and products after consumption point. Return polices with incentives help to drive the flow of materials and products through the supply chain. To ensure used engine cores are retained, machinery manufactures caterpillars uses a deposit- return system. There are then remanufactured and sold.
To streamline the return of usable, materials to the economy, DHL partners with refuse and recycling operations to streamline return of usable materials to the economy. To maximize the value of returned materials
streams and plan ahead based on a known inventory, DHL relies on the efficiency of the organization data tracking network.

Figure 4: Caterpillar - a world leader in reusing, reducing, reclaiming and recycling materials

2.4 LOOP
To increase the probability of effective reuse and second use for materials and components focus must be made on this assembly during the design phase. Greater integration of recycled components and materials from other industries is also enhanced.
(i) Products and components remanufacturing and refurbishing construction wastes are reduced, running cost are minimised while components and structures are kept in use for longer.
Also modularity and disassembly allows the structure to be changed easily while reducing waste.
Caterpillars remanufacturing facilities have salvaged beyond 500,000 tonnes of materials in the past decade. A typical manufacture of a cylinder head by caterpillar in one of its machines leads to: 93% reduction in water use, 36% reduction in energy use, 61% reduction
ingreenhouse gases, 99% reduction in material use compared with new products, and 99% reduction in waste to landfill (Amp, 2016)
(ii) Materials Recycling
Cutting of costs, earning revenues for stakeholders in the built environment, reduction of resource use and waste minimisation are advantages of recovering and recycling.
Components standardisation increase recyclability. Buildingsand structures can be designed to allow component parts to beeffortlessly disassembled and recycled. Significant reduction in carbon emissions and mitigation of price fluctuations are advantages of designing for reuse.
Identification and recycling of steel and other components is part of the online database and inventory created by Maersk to help/service the shipping industry. Compared to conventional instruction, a building client can benefit from significant savings on material cost – up to 25%

2.5 VIRTUALISE
(i) Using virtual means to displace resource use
Digital technologies have almost replaced physical market places. Supply matches demand virtually making it easier to share, exchange goods and services.
High-street rental shops such as Blockbuster has been replacedby virtual entertainment services like Netflix, while traditionalmusic outlets are being replaced by Spotify and sound cloud.
For the built environment, users wanting to lend or borrow infrequently – used household items such as tents, drills, lawnmowers, etc are connected through virtual marketplaces like peer by and street bank.
(ii) using virtual services to replace physical products and services Building information Modelling (BIM) is increasingly being used tocommunicate information to stakeholders in respect of ass phases of an assets lifecycle. Designers, contractors and building operators getrequisite information regarding an asset through its

life, BIM thuscollates data through its monitoring process to enable better informed upgrades, maintenance and modifications.
With BIM multiple stakeholders collaborate more efficiently on design, construction and operation of infrastructures.
The state-of-the-art sewage treatment facility designed by Amp in Hong Kong was facilitated by a BIM. The coordination, drawings production, operation and maintenance simulation plus material take-off for the design and construction of the facility were aided by development of 3D models. The models facilitated discussions between disciplines thereby leading to the design
(iii) Virtual Location replacing Physical Ones
Physical experience of a face-to-face meeting is achieved via a virtual platform as in video conferencing and virtual meeting rooms via platforms such as laptops, tablets, smartphones, FaceTime, skype and zoom, information can be shared by participants and documents presentation too.
Virtual testing and optimisation of designs are enhanced by these technologies.
(iv) Remote Service Delivery
The life of built environment assets can be extended using embedded sensors and smart monitoring devices that decode/discover problems and carry out maintenance to checkmate them. Efficiency gains are created; waste are minimised while assets life are prolonged.
This resources spent on physical maintenance activities are saved. The construction of wikitime 4.0 in 2014 is the world's first open-source, digitally manufactured 2 storey building which is part of the London design festival. The project was constructed in 12days and under
£50,000

Figure 5 Wikihouse – is the world's first open source house that anyone can download, digitally manufacture and assemble for themselves in days, with no
construction skills.

2.6 EXCHANGE
(i) Resources and technology must be wisely selected The pace at which new approaches are developed and adopted are catalysed byDigital technologies.
Stakeholders are on the lookout for efficiency gains, minimisation of wastes and other negative externalities. Increase in efficiencies result from new business models such as leasing, performance based models and flexible use design.
(ii) Replacements must be with renewable energy and material sources generating energy and heat through closed-loop systems such as anaerobic digestion, or using wind, solar and other renewables are part of the low- and zero-carbon strategy. Through these systems, carbon emissions are lowered
while associated externalities created by burning fossil fuels such as air pollution and other environment costs are minimised or eliminated.
(iii) Alternative Material inputs are used
Environmental impacts and costs can be lowered by changing the way products and materials are selected, manufactured and used in the built environment. Materials that are heavily processed and hard to reuse and recycle can be replaced with biological nutrients and sustainable, renewable materials.
Resource management company Veolia has discovered that under certain wastewater treatment process can convert sewage sludge into valuable bio- polymers for plastic and chemical industries. This helps in minimising waste while creating value for partners and customers.
(iv) Using advanced technology to replace traditional solution
Advanced and new technologies with innovation are being designed for modular repairs, flexible upgrade, active disassembly and longer lifecycles. 3D printing and LEDs are more cist and energy efficient, more durable and longer lasting than the conventional incandescent light bulbs. 1 LED light bulb can replace 25 incandescent light bulbs.

(v) Replacing product-centric delivery models with new service centric ones.
Delivering service or an output instead of selling a product is the target of performance-based contracts. Components like office furniture or lighting are leased to an asset operator or owner through this model. There is an attached incentive for the asset owner to return the productsat the end of their useful life for reuse, recycling or repair. Note that whatthe customer pay for is the desired outcome like lighting up a spaceinstead of ownership, installation and maintenance. This use of products are thus maximised while wastes are reduced to the barest minimum.
Examples
a. At the Amsterdam's Schiphol Airport, Philips provides lighting as a
service on a responsible
b. At the new National Union of Students (NUS) building in London,Philips provides a similar solution and retains ownership of allthe equipment while leasing the lighting services on contract basis for 15 years renewable. A guarantee to maintain at least 70% of its output standard is included in the contract.

3.0 NOTES ON APPLICATION OF CIRCULARITY AT SCALE

Presently it is only at the individual component level or asset level that circular practices occur.
Modular, prefabricated and off-site construction, designing for disassembly, designing out waste, materials reuse and recycling are some of the circular practices implemented now. Through the built environment is starting to see the value and wafting To catalyse action, with aberration and exemplars are essential to guild the process and boost the stakeholder's confidence while policy and norms for governance and procurement world help in creating the enabling environment.
The following note are necessary triggers for circularity implementation. "In London, circular economy opportunities in the built environment will add £3-5bn to GDP by 2036" – Arup, 2016 Exemplar intervention specifically for London are:
"Modular construction using 3d printing and addictive manufacturing could reduce structural waste and building times delivering a benefit of over £800m per year" – Arup
"Making more use of buildings through peer – to – peer renting, Office sharing, and multi-purposing buildings could save over £600m a year by doubling the utilization rate of 20% of buildings by 2036" – Arup "Design for building disassembly, material management and reuse with efficient disassembly technique, material passports, innovative business models and logistics could save over £200m" – Arup Other notable circularity advantages exist for infrastructure, cities, Regional and National, and Global.

4.0 CONCLUSION

In the words of Forbes McDougall, "the circular economy approach helps build better relationships with customers. In the built environment, it'sa business opportunity and a necessity you have to stay ahead, if you don't someone else will come and take that business away. But you have to find the right customers and partners. You can't do this on your own".
The potential macro-economic, social and environmental impacts coifrcularity interventions on GDP, job creation and CO2 emissions are enormous. Macro- economic indicators such as resource taxes, technology changes and adapting consumption patterns etc are impacted greatly.
No doubt that circularity transition
requires some degree of policy intervention so as to generate incremental macro- economic and social benefits, as well as sizable environmental benefits (Glenn A. Anguilar-Hernandez et al, 2021). Circular Economy is therefore the way of the future in the built environment considering the obvious economic, social, environmental benefits. We all need to change our ways of engineering things to benefit all stakeholders, cities, regions, countries and the world at large.

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