World Academy of Science, Engineering and Technology
International Journal of Economics and Management Engineering
Vol:16, No:10, 2022

Transformation of Linear Economy to Circular Economy in Hong Kong Building and Construction Industry

Kwok Tak Kit

***Abstracts*—**This research focuses mainly on the transformation of circular economy and specifically on the building and construction industry in Hong Kong. This research is going to investigate the current status of development and transformation of linear economy of Hong Kong into circular economy. The research is based on literature review and different published reports to outline the possibilities for further development and transformation of circular economy in Hong Kong. Different key factors affecting the transformation particularly in building and construction industry are discussed.

***Keywords*—**Circular economy, LEED net zero, carbon emission, waste reduction, waste management.

I. Introduction

THE role of building and construction sectors in the transformation of Hong Kong linear economy to circular economy is discussed. This paper investigates the potentialities of further development of building and construction technology and assessment tools to optimize the implementation of reducing, resuming and recycling in building and construction industries to achieve the development of circular economy and transformation of linear economy to circular economy. This reach will identify different key elements in building, construction in residential, commercial and infrastructure for stakeholders to further review and increase their interests in the circular economy.

Background of Paris Agreement 2015 and COP 2021

Under the Paris Agreement 2015, all parties to the agreement began submitting climate action plans known as nationally determined contributions (NDCs) in 2015-2017. In COP26 climate talks 2020-2021, members have begun revising their NDCs to strengthen climate action and to reduce the carbon emissions and ultimately reach the net zero targets by 2050. Subsequent to the Paris Agreement 2015, the 26th United Nations Climate Change Conference (COP26) was held in Glasgow in 2021. In the Submit, all countries agreed to the Glasgow Climate Pact to maintain 1.5 degrees and target to finalize the outstanding elements of the Paris Agreement.

Concept of Circular Economy

In Hong Kong, the government and property developers are increasing their attention and concern on the reduction of carbon emission in the building and construction industry and looking for the opportunities to transform the linear economy to circular economy to tackle climate change and meet the global commitment to net zero goal under Paris Agreement. Ellen MacArthur Foundation [6] defined circular economy as a model of the economy based on three principles:

- Designing out waste and pollution
- Keeping products and materials in use
- Regenerating natural systems

Hong Kong is well known as one of the most densely populated cities in world and the annual generation of 6 million tonnes of wastes [7], [18] Circular economy development in Hong Kong is still in early stage due to the limitation of economic structure and geology factors. The Hong Kong economy structure focused on the commercial and service industry while recycling business and facilities particularly in the building and construction industry are not well developed in the past decade. Most of the waste generated in Hong Kong depends on dumping sites or exports.

The adoption of the fundamental 3R concept – reducing, reusing and recycling in Hong Kong linear economy approach in building and construction industry has been ignored while promotion and governing of waste management and carbon emission is far beyond the development in other countries.

II. Circularity in Hong Kong Building Construction Sector

With the rapid urbanization and fast growth of infrastructure demand in Asia cities, more concern should be focused on the building and construction sector. Building and construction processes involved various macro and micro stages, mainly demolition, site formation, foundation, construction and maintenance. Great potential of the circular economy concept can be deported in various stages at an early stage that would involve generation of waste, use of material resources and energy. Proactive and advanced planning to harvest the reusable material during demolition, use of renewable and recycled building material, advanced building construction methodology and monitoring of energy consumption are considered crucial to achieve the balance of carbon and built for sustainability.

In reality, most of the construction and demolition (C&D) waste generated during the building and construction process is directly disposed to the dumping site without going through any material sorting and recovery strategy. Waste water generated from construction is treated and then discharged

Kwok Tak Kit is with DLN Architects Limited, Hong Kong (e-mail: tkepisode@gmail.com).

without any planning to recycling of the treated water to support the water use of the building construction site. Under the conventional construction methodology, most of the building materials particularly for internal finishing involved huge amounts of unwanted plastic or paper protection and it is all disposed on site and delivered to the dumping site as C&D waste without proper planning for recycling.

Hong Kong is a linear economy and the waste management solely replies on the take-make-dispose approach. Once the required amount of raw material is transformed into final product, the excessive material will be disposed or exported to other countries.

Conventional building construction process including final fixing and assembly of building components are all mainly carried on-site. Therefore, substantial amount of building material wastage is generated. In terms of the profitability and lack of recycling mechanism and facilities in Hong Kong, most of the temporary works used on construction site like bamboo scaffolding, timber formwork, and other temporary protection are usually disposed directly to landfill.

According to the Waste Statistics for 2019, Environmental Protection Department, [7], [18] the total disposal of C&D waste at landfill is around 25% of total waste generated. Fig. 1 and Table I show the direct relationship of construction waste generation and GDP from 2015 to 2019.

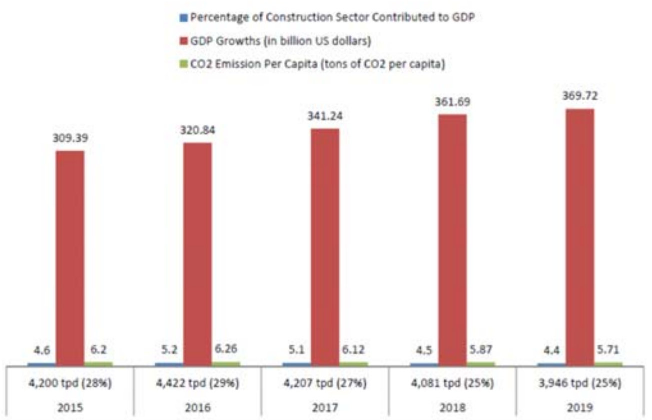

Fig. 1 Relationship of Construction Waste Generation, GDP and CO_2 Emission in Hong Kong [18]

TABLE I
RELATIONSHIP OF CONSTRUCTION WASTE GENERATION, GDP AND CO_2 EMISSION IN HONG KONG [18]

Year	Disposal of Construction Waste at Landfills in Hong Kong (% proportion to overall generation)	Percentage of Construction Sector Contributed to GDP	GDP Growths (in billion US dollars)	CO_2 Emission Per Capita (tons of CO_2 per capita)
2019	3,946 tpd (25%)	4.4	369.72	5.71
2018	4,081 tpd (25%)	4.5	361.69	5.87
2017	4,207 tpd (27%)	5.1	341.24	6.12
2016	4,422 tpd (29%)	5.2	320.84	6.26
2015	4,200 tpd (28%)	4.6	309.39	6.20

With the limitation of suitable landfill and incineration plants in Hong Kong, further development and innovation of waste reduction and effective treatment of waste is becoming more important. [11] The government has also launched the Waste Blueprint for Hong Kong 2035 to clearly explain the vision and road map to cater for waste reduction, resource circulation and zero landfill. [7] In the blueprint, the government planned to encourage the construction industry to carry out source separation and develop construction waste sorting facilities to recycle and refuse the construction waste more efficiently. Adoption of construction methods such as modular integrated construction methods can reduce construction waste at source [4].

III. NET-ZERO CARBON EMISSION IN BUILDING AND CONSTRUCTION INDUSTRY

A. Reduction of Energy Demand

The optimization of the energy efficiency facilities and building is the major factor for decision making in the building and infrastructure construction planning stage. During the design phase, pre-assumption energy strategy plan has to be carefully and holistically assessed in order to reduce the energy consumption to a certain level.

The pre-assumption energy strategy plan can meet the high energy performance and the inclusion of sustainable architectural design, sustainable engineering and adoption of extensive renewable energy supply. Instead of achieving the minimum regulation standards, a performance-based assessment and methodologies should be carried out in the design stage to estimate the expected energy consumption with reference to client expectation, estimated occupancy and intended use to achieve the optimization of future operational energy consumption and provide a more accurate reflection of energy consumption.

B. Reduction of Embodied and Upfront Carbon

Building construction industry generated significant amount of carbon emission during the process of manufacturing, transportation and construction. Embodied carbon emissions are produced primarily before a building is operated and decommissioned. The upfront embodied carbon emission is associated with the construction of a building and it cannot be later improved.

In the early design stage, the selection of net zero embodied and upfront carbon is critical to achieve the decarbonization. With the aids of the local and internationally recognized environmental assessment tools, best practice of embodied carbon reduction strategy and monitoring the whole construction process and final performance of buildings can be achieved [3].

In the past few years, the concern of construction carbon emission during the building cycle and reducing embodied carbon is increasing in the AEC industry. In most of the transport, infrastructure and building and construction enabling building and infrastructure projects, the AEC can only rely on their own professional judgment with client commercial decisions on the selection of low upfront embodied carbon building material to minimize the impacts in the construction phase as practically as possible. Publication by the World Green Building Council [21] recommended the target of reducing the construction-related embodied carbon by 40% by 2030 which is being a latest guideline for AEC to make reference in their new projects. In new planning of transport, infrastructure and building and construction development, practitioners should also make reference to other international guidelines and life cycle carbon assessment during the planning and construction phase to achieve the net zero target by reducing the use of upfront embodied carbon material in view of the environmentally sensitive nature of transport, infrastructure and building and construction development.

C. Green Energy and Renewable Energy Supply Adoption in Construction Site

The problem of heavily relying on national fossil fuel power supply in transport, infrastructure and building and construction enabling development is a prime concern. Adoption of on-site generation of low carbon heat and hot water supply, advanced technology development in energy storage as well as renewable energy for decarbonisation can be more practically implemented with the support of government agents and aggressive stakeholder's vision.

D. Reuse and Recycling of Building Material under "Central Building Material Donation Bank Scheme"

Dumping and disposal of building material during construction directly from construction site to public landfill is the transition treatment method. More advanced redundant building material and C&D waste sorting should be carefully sorted on site. Redundant building material can be reused in other projects while 100% C&D waste sorting plan should be compulsory imposed in all public and private building and infrastructure contracts and projects. The government can establish a "Central Building Material Donation Bank Scheme" to collect the redundant building material released in large scale private and public projects and sell to the market at low cost to promote the re-use of redundant building material in small scale buying, construction and refurbishment, transitional housing and public facilities projects which could help to minimize wastage and disposal to landfill. [2]

E. 100% Wastewater Reusing and Recycling on Site

The effluent generated from construction site is mainly generated from the following activities:

- Waste water generated from construction activities including bore pile foundation construction
- Truck and concrete loader cleaning water
- Site cleaning water
- Ground water collected inside construction site
- Rain water
- Water spray for dust removal

The reuse and recycling of construction waste water depends on the treatment facilities and the quality of treated wastewater. Conventionally, the construction wastewater is treated by a sediment tank and then discharged to the government storm water drainage system. Adoption of advanced and effective wastewater treatment plants together with use of effective chemical agents enhanced the sedimentation efficiency and quality of reclaimed water. Similar wastewater treatment and technology is well developed in Hong Kong, for example, "AquaSed" wastewater treatment system developed by Hong Kong Productivity Council (HKPC) with the use of advanced proportional dosing technology to adjust the quality of construction wastewater [20]. To regulate the maximization of reuse and recycling of construction wastewater, the government can impose 100% reuse and recycling of construction wastewater generated on site and provide incentive to the stakeholders to increase their interest to adopt the policy.

F. Circular Economy and Innovation of Advanced Technologies

Circular economy concept comprises the reducing, reusing and recycling in production, processing, consuming technologies. It aims to reduce the consumption of finite resources and provide economic natural and social capital. It is a systems level approach to economic development designed to benefit business, society and the environment. Adoption of the principle of circular economy can reduce the waste pollution and maintain the products and materials in use. Finally, the products and materials can be regenerated to natural systems. Circular economies can help to reduce carbon emission and provide opportunities for reducing resource demand and waste, increasing biodiversity gain and mainstreaming health and well-being opportunities into the built environment. Government should establish a clear policy for banning the import of waste including waste fiber, plastics, glass, tires from other countries and encourage the recycling of waste generated locally. During the planning and construction stage, the circular economy approach can improve the environmental performance with the use of modular construction method to effectively use the building components and materials. Circular economy principle enhances the use of renewable energy and adoption of new technologies to improve the energy and resources efficiency in building during the operation stage [12].

G. Transportation

Since the transportation sector is well known as the largest share which generates greenhouse gas emission as the greenhouse gas emission comes from burning fossil fuel from trunk and machinery plants, promotion of the use of the electrical charging trunks and development of more advanced technology of electricity operated machinery can significantly reduce the reliance on conventional transportation models.

IV. Building Information Modeling

The benefits of adopting BIM can significantly reduce errors, reducing unwanted rework on site. Early adoption of BIM in the design stage can facilitate and streamline the process of design and future manufacturing and installation [13]. The development of BIM in developed countries during the past 10 years has seen a breakthrough from conventional

3D/4D level BIM for crash analysis then up to 5D/6D/7D level BIM to achieve higher levels of benefits [5], [10]. The 5D BIM can achieve more cost control aspects while further wide adoption of 6D BIM can greatly achieve the sustainability goal.

Design for Manufacture and Assembly/Modular Integrated Construction/Prefabricated Prefinished Volumetric Construction

Modular integrated construction design with the aid of high level of BIM technology can minimize the resources and demand of skilled labor and different trades including MEP can be manufactured and fabricated in offsite prefabrication factories independently to achieve centralized material storage, recycling and waste sorting in specific trade factories effectively. [16] Promotion of the use of renewable energy in prefabrication factories also encouraged the adoption of renewable energy. Different components can then be accurately fabricated in individual factories up to the required standard [14], [15] under a controlled environment before delivered to the prefabrication factory for assembly and delivery to site for immediate installation. This can reduce the unwanted pollution, material wastage and enhance the control of time, cost and site safety [19]. Point-to-point construction also reduces the unnecessary pollution generated at those pollution sensitive construction sites and shortens the overall construction cycle.

Environmental Assessment Tools, Methods and Certification and Innovation

There are various environmental assessment tools and certification developed in different countries (BEAM Plus (HK), LEED (US), WELL (US), BREEAM (UK), Green Star (Australia), Green Mark (Singapore)) but the common goal of adoption of various tools is to meet the global trend to reduce environmental impact and achieve sustainability during construction and operating cost particularly in significant cost saving on energy and water. The combination of use of the environment assuagement tool and building information models (BIM) creates a synergy to achieve a high standard of sustainability [1]. The BIM model can be used in the design stage with the assistance of different computational simulation tools to ascertain the design assumption made in environmental assessment tools and monitoring the whole construction process which can be in line and meet the requirement under regulation and client expectation. One of the major advantages in environmental assessment and certification is their encouragement of innovation of building design, technology and construction methods and it plays an important role in the promotion of technology development.

LEED and LEED Zero Accreditation for Verification of Sustainability Goals

Once the buildings achieved the LEED certification, the building owners can pursue further transformation by using LEED Zero to verify their achievement of net zero goals. Building owners can pursue multiple LEED Zero certifications concurrently [17].

LEED Zero provides a user-friendly and internationally recognized platform for building which has achieved a certain standard of LEED accreditation to complement their existing LEED certification with one or more of the LEED Zero certifications in Table II [17].

TABLE II
LEED NET ZERO CERTIFICATION SCHEME

Type of Net Zero Certification	Certification
LEED Zero Carbon	It is to certify and accredit building which achieve the balance of carbon emission generated from energy consumption and transportation to avoid and offset carbon emission. It encourages the carbon balance and reduce carbon emission during waste consumption and generation and the release of embodied carbon of building material used
LEED Zero Energy	It is to certify accredit buildings that achieve the source energy use with balance of zero
LEED Zero Water Certification	It is to accredit buildings for achievement of a potable water use balance of zero
LEED Zero Waste Certification	It is to accredit buildings that achieve GBCI's TRUE Zero Waste certification at the Platinum level

Sustainable Procurement

There is a growing trend in the building and infrastructure construction industry to adopt sustainable procurement in accordance to ISO 20400. [9] Perhaps, it is hard to achieve in terms of culture, business model and commercial decision. With the assistance and promotion from the government, practitioners are now willing to adopt and build a sustainable supply chain for the future and make the commitment to social responsibilities.

Benefit of Circular Economy Development

Transformation and development of circular economy in building and construction I industry provides many major benefits to the industry and the economy as compared with traditional building and infrastructure construction practice including:

- Minimize the intensive demand of skilled construction labor with the concern of ageing population
- Create opportunities for A/E practitioners to diversify their professionals
- Create jobs for other sectors with collaboration of different expertise and profession
- Reduce environment impact caused to the environment and community
- Reduce carbon emission, greenhouse gas emission and provide long term strategy to tackle environmental impact
- Add value to building projects and increase industry reputation
- Reduce government resources used in construction waste treatment and material sorting
- Increase the productivity, durability and sustainability of building and infrastructure
- Drive greater resource productivity
- Deliver a more competitive economy

V. CONCLUSION AND RECOMMENDATION

Based on the research and studies on different key elements which significantly contributed to the development and transformation to circular economy in the building and construction industry, there are some key recommendations listed below for further review, discussion and research [8], [16]:

- Government which is responsible for coordinating, compiling, storing and promoting information and standards for the production and use of recycled products. Incentive shall be provided by the government in order to encourage the stakeholders to adopt the use of recycled C&D material.
- Regulatory approach to support the sustainable resource use and pricing of recycled material like recycled aggregate as an alternative to virgin aggregate.
- Promotion of the use of sustainable procurement practices in government and private building, construction and infrastructure projects to widely adopt the recovered C&D material in the industry.
- Collaboration with university and stakeholders for investment in development of processing technology.
- Investment in government facilities for effective sorting of mixed waste to increase the recovery rate of C&D resources.
- Impose of new regulations to prohibit the landfill disposal of untreated and unsorted C&D waste.
- Encouragement of the use of advanced prefabricated and modular construction to replace the conventional building method and improve human behavior in government projects.
- Compulsory implementation of different international assessment tools for building, construction and no infrastructure projects like LEED Net Zero.
- Promotion of green energy and renewable energy supply adoption in construction site.
- Establishment of "Central Building Material Donation Bank Scheme" to collect the redundant building material released in large scale private and public projects.
- Promotion of 100% wastewater reusing and recycling on site.
- Early adoption of carbon and waste reduction approaches to meet the upcoming implementation of infrastructure plan in post COVID-19 stage.

In the post COVID-19 stage, most of the countries are preparing to boost the economy (GDP) growth by rapid implementation of infrastructure. Early action to plan for the predicted increase of waste generation and CO_2 emission in building, construction and infrastructure is becoming prominent.

REFERENCES

[1] Ahmad Nazri Muhamad Ludin, Environmental Assessment Tools and its Rating system: A Review, Australian Journal of Basic and Applied Sciences · July 2013
[2] Chakkrit Luangcharoenrat, Singh Intrachooto, Vachara Peansupap, Wandee Sutthinarakorn, Factors Influencing Construction Waste Generation in Building Construction: Thailand's Perspective, Sustainability 2019, 11, 3638
[3] Christian, Yun-Tsui Chang, Shang-Hsien Hsieh, BIM-based Assessment of Building Circularity and Embodied Carbon for a Circular Built Environment, 2021 Conference on Computer Applications in Civil and Hydraulic Engineering, August 30-31, 2021 at National Central University, Taiwan
[4] Construction 2.0 Time to change, Development Bureau, HKSAR
[5] Dan Zhang, Wei Lu, Steve Rowlinson, Exploring BIM implementation: A case study in Hong Kong, Department of Real Estate and Construction, The University of Hong Kong
[6] Ellen MacArthur Foundation. (n.d.). Concept: What is a circular economy? A framework for an economy that is restorative and regenerative by design. Retrieved from https://www.ellenmacarthurfoundation.org/circular-economy/concept
[7] Environmental Bureau, Waste Blueprint for Hong Kong 2031, February 2021
[8] Hyder Consulting, Encycle Consulting & Sustainable Resource Solution, Construction and Demolition Waste Status Report, Management of Construction and Demolition Waste in Australia, Report No.5, 20 October 2011
[9] Matthew Kalubanga, Sustainable Procurement: Concept, and Practical Implication for the Procurement Process, International Journal of Economics and Management Sciences Vol.1, No.7, 2021 pp.01-07
[10] Nam Bui, Christoph Merschbrock, Bjorn Erik Munkvoid, A Review of Building Information Modeling for Construction in Developing Countries, Procedia Engineering 164 (2016) 487-494
[11] Nell Fabian, Loretta Leong Tak Lou, The Struggle for Sustainable Waste Management in Hong Kong: 1950s-2010s, Worldwide Waste: Journal of Interdisciplinary Studies, 2(1): 10, 1-12
[12] Guillermo Aranda-Mena, Paulo Vaz-Serra, Building Circularity in Infrastructure and Commercial Construction, Conference Paper · October 2021
[13] Tianqi Yang, Lihui Liao, Research on Building Information Modeling (BIM) Technology, World Construction Volume 5 Issue 1, August 2016
[14] Reference Material - Sample Clauses for Procurement of MiC Building Projects, September 2021, Construction Industry Council
[15] Reference Material - Use of Digital Technologies for QA/QC of MiC Modules in MiC Factory, September 2021, Construction Industry Council
[16] Tom B J Coenen, Leentje Volker, Klaasjan Visscher, Introducing Circular Innovation in the Construction Industry: The case of the Circular Viaduct, Conference Paper · September 2021
[17] USGBC, LEED Zero Program Guide, April 2020
[18] Waste Statistics for 2019, Environmental Protection Department
[19] Weisheng Lu, Tan Tan, Jinying Xu, Jing Wang, Ke Chen, Shang Gso, Fan Xue, Design for Manufacture and Assembly (DfMA) in Construction: The Old and the New, Architectural Engineering and Design Management
[20] WF Chan, Construction Wastewater Treatment System, Hong Kong Productivity council 31 May 2018, www.HKPC.org