A framework of total low carbon management paradigm in building industry

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Abstract

Low carbon practice becomes a global appeal for addressing climate changes. As a major carbon emission sector, building industry has the liability to take all possible actions for reducing carbon emissions. This paper introduces a principal framework of total low carbon management (TLCM) paradigm in the context of building industry. It argues that building industry must engage an advanced management paradigm in order to make effective contributions to the goal of emission reductions. And this paradigm requests the participation of low carbon practice across the whole regulations, the whole industry, the whole building enterprise, the whole building staff, and the whole building process.

1. Introduction

It becomes the common knowledge that the warming climate presents the biggest threat to the sustainability of humankind. According to "2022 Global Climate Status Report" issued by World Meteorological Organization, the real-time data indicate that global emissions continued to increase in 2022. The global temperature changes from one year to the next. The last eight years (2015-2022) are the warmest on record. Responsive measures have been introduced and implemented both locally and internationally. Typical examples include the implementation of Paris Agreement issued by IPCC (Intergovernmental Panel on Climate Change) at UN Climate Change Conference in Paris in 2015, with the aim of tackling climate change and its negative impacts, in particular, with the specification of reducing global greenhouse gas emissions to hold global temperature increase to well below 2°C above pre-industrial levels and pursue

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efforts to limit it to 1.5°C above pre-industrial levels, and the Kyoto Protocol issued at the third conference of the parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto, Japan in 1997. The designation of dual carbon targets is overwhelmingly accepted as an important instrument to promote low carbon development across different countries. For example, the Chinese government has set its ambitious dual carbon targets of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060. On the other hand, public have also become more conscious of our sustainability and responsibilities in addressing climate change by taking all possible actions on the reduction of emissions. Most of people start to ask the question: "What can I do in reducing carbon emissions?"

However, the climate remains changing continuously with the increase of temperature. According to the recent analysis by the Copernicus Climate Change Service (C3S), 2023 was the hottest year on record in many countries throughout the world, and more than 200 days in 2023 set new daily global temperature records. It was estimated that there is a good chance for 2024 to be even hotter than 2023 (WMO, 2024). These facts may spell out that previous actions against climate changes are of limited effectiveness. It is therefore important to study alternative solutions for enhancing the effectiveness of emission reduction particularly in those major emission sectors such as building industry.

Building industry is widely appreciated as a major emitter globally. According to the report "Research Report of China Building Energy Consumption and Carbon Emissions (2022)", the life cycle carbon emission in construction sector in China in 2020 was 5.08 billion tons, accounting for 50.9% of the total national carbon emissions, and that the life cycle energy consumption in construction sector was 2.27 billion tons, accounting for 45.5% of the total national energy consumption. And these figures remain increasing trends. Similar statistics are also reported by researchers in other countries. There is every reason to argue that building industry has major responsibility to move towards low carbon industry. In other words, low carbon practice in those emission-tense industry such building should play the key role in promoting low carbon development. Therefore, future building industry must be low carbon driven industry. In order to achieve this, the industry should move beyond the traditional technological solutions to a new management paradigm in order to achieve low carbon building industry.

Previous studies have presented extensively various measures in technological domain to combat against carbon emissions in building industry. Governments internationally have introduced many measures and regulations over previous several decade for promoting green building industry, typically such as various green building systems, typically, BREEAM (Building Research Establishment Environmental Assessment Method) introduced in UK in 1990 (it is one of the world's most popular environmental assessment methods and rating systems for buildings), HQE (High Quality Environmental standard) in France in 1996, HKBEAM (Hong Kong Building Environmental Assessment Method) in Hong Kong in 1996, LEED (Leadership in

Energy and Environmental Design) in US in 1998 (which is a worldwide recognized system to determine the sustainability of buildings. It looks closely at spatial development, water-saving schemes, material selection, indoor air quality and innovation), Green Star in Australia in 2003, Green Mark in Singapore in 2005, GG/T50378 (Green Building Appraisal Standard) in China in 2006, DGNB (Deutsche Gesellschaft fur Nachhaltiges Bauen) by German Sustainable Building Council in German in 2007 (it is the common German rating method for sustainability, in rating grades, namely, bronze, silver, gold, and platinum).

Nevertheless, there is little existing study investigating how management paradigm should be transited from traditional practice among these key emission industries. Without the shift of management paradigm among these key emitters such as building industry to targeting emission reduction, the limited effectiveness would remain for achieving the goal of low carbon future. There is therefore a pressing need to investigate how management paradigm among the key emission industries such as building should be transited to a new paradigm that can be more efficient and effective to reduce carbon emissions. In line with the above background, this paper aims to introduce a principle-based framework of total low carbon management (TLCM) paradigm.

2 Typical management paradigms in building industry

Based on a comprehensive literature review on the subject of building industry management, we have classified the management paradigms in building industry into three broad categories: management theory driven paradigm, technology driven paradigm, and sustainable development value-oriented driven paradigm. A list of these classifications are suggested as follows:

Theory driven management paradigms

- Construction management
- Decision support system
- Project management
- Cost management
- Quality management
- Contract management
- Information management
- Risk management
- Human resource management
- Others, …

Technology driven management paradigms

- Building information modelling
- Building management systems
- Computing technology application
- Automated construction management systems
- Big data

- Internet
- Deep learning
- Others, …

Sustainable development value driven management paradigms

- Construction safety
- Labor and personnel issues
- Climate change
- Energy application
- Thermal comfort
- Smart building
- Energy conservation
- Energy management systems
- Sustainability
- Others, …

The review on the existing management paradigms in building industry suggests that the earlier management paradigms are mainly associated with theory-driven domain. The technology driven management domain appears after the burst of theory-driven domain, typically such as “computer applications”, and “BIM”. It is worth of noting that the management paradigms related to the sustainable development, which can be called sustainable development value driven management paradigms, have been occurring as research hotspots in late years, such as "construction safety”, “smart buildings", "thermal comfort", and "smart buildings". These sustainable value-oriented conceptions are actively promoted in recent years, and they are closely related to the aspects of low carbon and healthy living environments, which put priorities to people’s values and interests. This indicates that the sustainable development value-oriented management paradigm domain has become an important direction for developing building management methodologies. In line with the development of the research domain into accounting for sustainability and people-oriented values and interests, this paper will discuss what management paradigm will be developed to guide the future building industry towards low carbon building practice.

3 A principal framework of total low carbon management (TLCM) paradigm

In order to address the question of management paradigm for guiding future building industry towards low carbon practice, systems approach is adopted to examine the development of management paradigm within building industry.

Building industry is a very dynamic and complex system which interacts closely with external constraints and conditions. The major elements or subsystems within this complex system can be broadly identified into five components, including government departments, building organizations, building personnel, building processes and building activities, as shown in Figure 1. Among these subsystems, “government departments" makes laws and policies, thus it is the dominant sector or order parameter (in synergetic term) according to the principle of that law is above all.

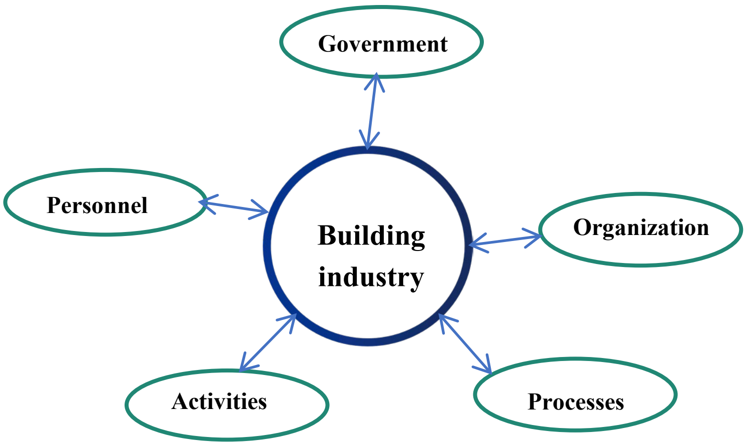

Figure 1. The system of building industry

On the other hand, the promotion of low carbon development has become the key strategy internationally for addressing the challenge of climate change, and this international move has been endorsed by the governments in all countries (Zhao et al. , 2022). Accordingly, governments internationally are determined to implement low carbon policies. In referring to the principle of synergetic theory, other subsystems in the building system will follow the dominant subsystem's suit to engage low carbon practice (Haken, 1983). As a result, the whole building industry will engage low carbon practice, which can be called total low carbon management paradigm (TLCM). In other words, TLCM paradigm requests for low carbon actions in Whole regulation, Whole industry, Whole enterprise, Whole staff, Whole process by means of modifying building and construction codes, reforming construction contract terms, saving construction energy, replacing fossil with non-fossil fuel, offering the public with low carbon construction products. The 5Ws (Whole regulation, Whole industry, Whole enterprise, Whole staff, Whole process) form an integrative system for promoting total low carbon management (TLCM), as shown in Figure 2.

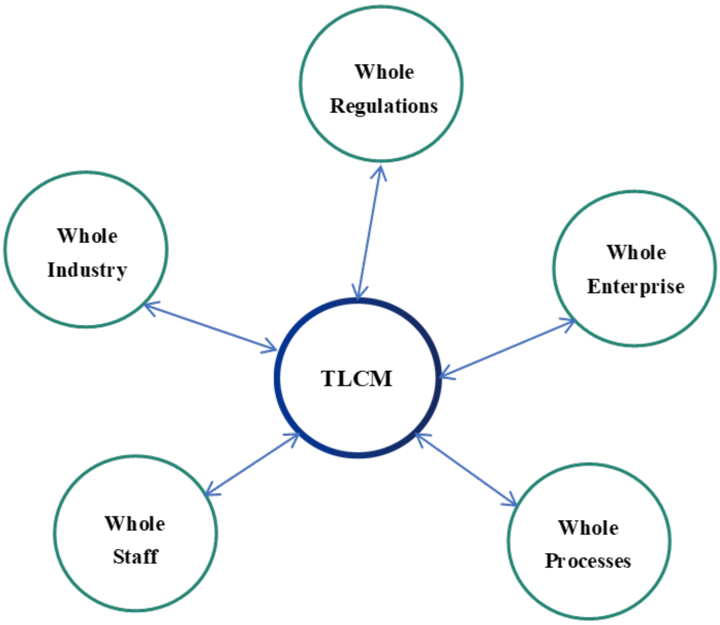

Figure 2. The integrative system by 5Ws for the promotion of TLCM

Low carbon management by Whole Regulations

TLCM requests the design and implementation of **whole regulations** to guide the building industry towards low carbon practices:

The government department, as the leading element, needs to design and implement regulations for guiding the whole context within the building industry towards low carbon practice, specified as whole regulations (IEA, 2013, Van der Heijden, 2016, Zapata-Lancaster and Tweed, 2014).

In a typical case, the government should consider imposing the provision of an Environment, Social and Governance (ESG) report as part of tendering documents in the process of recruiting participants in the building industry, including construction clients, contractors, and consultants (Gunawardana et al. , 2021).

Low carbon management in Whole Industry

Low carbon actions in the **whole industry** should be across all types of enterprises along the chain of construction business, including, developers, clients, contractors, materials producers and suppliers, designers, contractors, consultants, and others.

Those companies with various advantages shall play demonstrative and leading role in taking actions to implement low carbon practice (Alam et al. , 2020, Giesekam et al. , 2016, Komkova and Habert, 2023, Lindberg et al. , 2020, Liu and Teng, 2023).

Low carbon management in Whole Enterprise

- TLCM requests the synergy for adopting low carbon practice from all departments within the **whole enterprise** by emphasizing corporate social responsibility, and promotes people-oriented culture and values within the whole enterprise.
- The enterprises applying total low carbon management paradigm will be engaged with ESG practice and assessment, and be strict with the enterprise itself in taking low carbon actions (Laosirihongthong et al. , 2013).

Low carbon management in Whole Process

- TLCM requests the application of low carbon measures for the **whole process** across construction life cycle:
- Low carbon planning (TOD, EOD)
- Low carbon feasibility study
- Low carbon design
- Low carbon procurement – requesting for ESG
- Low carbon construction
- Low carbon operation
- Low carbon demolition

Low carbon management among Whole Staff

TLCM requests the assignments for implementing low carbon measures to the **whole staff**. All members in construction sector have the responsibility of promoting low carbon behaviors.

Managerial staff should set examples in practicing low carbon behaviors (Zhu et al. , 2008).

Company should provide staff education and training on low carbon knowledge, empowering staff in practicing low carbon behaviors, and cultivating the low carbon culture among all the staff (Wu et al. , 2012).

4 Opportunities for the application of TLCM paradigm

The green development strategy and dual carbon targets designated by governments internationally provide construction industry with the opportunity of adopting total low carbon management paradigm. Governments worldwide are increasingly implementing stringent regulations and policies to promote low carbon practices. For example, the European Union's Green Deal aims to make Europe climate-neutral by 2050, enforcing strict carbon reduction targets across all sectors, including construction. This regulatory push creates a favorable environment for construction companies to adopt TLCM and benefit from compliance incentives such as tax breaks. Additionally, the UK’s Building

Regulations mandate energy efficiency and carbon reduction measures, encouraging the adoption of innovative low carbon technologies (Pan and Garmston, 2012). These regulations not only drive compliance but also open up new markets for green building products and services.

The multiple “wins” can be obtained between government, industry and enterprise through the practice of the new management paradigm. For instance, the growing consumer preference for sustainable construction products creates a significant business opportunity. Based on this trend, some companies have developed energy-efficient building temperature control systems, which greatly reduce building energy consumption and are welcomed by the market (Liu et al. , 2023). The increasing demand for green buildings is also reflected in the rise of green building certification systems such as LEED and BREEAM, which have become key driver in the market (Ferreira et al. , 2023). As more consumers and businesses seek out low carbon solutions, construction companies that adopt the TLCM paradigm will be well-placed to capture this growing market, driving both revenue and positive environmental impact.

TLCM paradigm can drive construction industry to transit to low carbon construction pattern. That will present opportunities for regenerating construction products, improving the quality of working environment in the industry, building up better and green image of the industry. In Australia, Lendlease is a leader in sustainable building practices, with its Barangaroo South project in Sydney being an example. Recognized as one of the most sustainable urban areas in the world, the project effectively reduces overall carbon emissions by integrating renewable energy, water recovery systems, and the use of sustainable building materials. In Hong Kong, Gammon Construction is a pioneer in low-carbon concrete technology. They are testing Carbon Cure’s technology, which involves injecting carbon dioxide into concrete during mixing, permanently sequestering the carbon dioxide and thereby reducing the overall carbon footprint by about 5%. These projects indicate how the TLCM paradigm create low-carbon urban spaces, enhancing environmental and social outcomes.

In the era of promoting low carbon society, the demands from the whole public for low carbon construction products will increase sustainably, which presents the great business opportunity to all types of enterprises along the construction chain both upstream and downstream businesses, such as low carbon supply, low carbon design, low carbon consultancy, etc. For instance, Building Information Modeling (BIM) is revolutionizing the construction industry by enabling comprehensive low carbon planning and management throughout a building's lifecycle (Gan et al. , 2018). Additionally, digital twins, as utilized by some advanced building technology companies, allow for real-time monitoring and optimization of building performance, significantly reducing energy usage and operational costs (Deng et al. , 2021). These technological advancements not only support the practical implementation of TLCM but also provide a competitive edge to companies that adopt them, driving innovation and sustainability in the construction sector.

TLCM is a new management paradigm with emphasizing on process control, which involves in multiple types of data and information. And digitalization tools make it possible to handle these data effectively. Digitalization tools such as Building Information Modeling (BIM) facilitate collaboration and data sharing at the industry level. For instance, BIM enables the creation of detailed 3D models with embedded data on design, construction, and maintenance, this holistic approach to process control ensures that sustainable practices are embedded throughout the construction lifecycle (Zhang et al. , 2022). At the enterprise level, the Internet of Things (IoT) offer precise control and monitoring capabilities. IoT devices can monitor and control various building systems, such as lighting, heating, and cooling, to ensure they operate efficiently (Deakin and Reid, 2018). By integrating digitalization into every aspect of the construction process, the TLCM paradigm facilitates a more efficient, sustainable, and low-carbon approach to building management.

5 Challenges for the application of TLCM paradigm

Although the low-carbon era presents significant opportunities for the total low carbon management in the building industry, implementing this paradigm still poses a range of specific challenges.

How to get a balance between economic benefits and low carbon social responsibility? In particular, low carbon practice in the building industry may confront challenges with people who are used to carry on a carbon-intensive life.

Total low carbon management paradigm is process-oriented. It is a challenge to change the traditionally outcome-oriented management mentality to a new pattern of process-oriented management paradigm.

Many business firms labelled with low carbon have been emerging internationally, such as low carbon supplier, low carbon consultants, low carbon research centers, low carbon contractors, etc. It is a challenge to form consensus between these stakeholders about standards and forms of low carbon practice in the building industry.

Furthermore, the fundamentals for promoting total low-carbon management in the future building industry are talents, and it is a challenge how to attract low-carbon talents to the building industry.

6 Conclusion

This paper opines that we have entered the era of low carbon development, and total low carbon management in the building industry is a new management paradigm imposed by this era.

As the government sector is the dominating element or order parameter within the building industry system, the other elements in the system will have to follow the suits of transiting to low carbon practice, including building organizations, building personnel, building activities and building processes. Accordingly, a total low carbon management paradigm will be in effect in the future building industry, composed of whole regulations, whole industry, whole enterprise, whole staff, and whole process.

The application of the TLCM paradigm may not happen in the short term. However, the argument on this new management paradigm in this paper sheds light on the low carbon development pattern in the future building industry. Practically, this paper demonstrates the necessity of culture and mentality transition to low carbon practice among building organizations and the personnel working in the industry.

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