Towards a Conceptual Framework of Construction Waste Management to Support Sustainable Development: the Case of Smart Integrated Construction System (SICS)

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Towards a Conceptual Framework of Construction waste management to Support Sustainable Development: The Case of Smart Integrated Construction System (SICS)

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ABSTRACT: With the development of urbanization, many projects transport waste, demolition waste, decoration waste, and so on leading to the growth of urban construction waste. Construction waste has become an urgent problem in environmentally sustainable development. This paper analyzes the status of construction waste in Singapore. Studying the application of Smart Integrated Construction System (SICS) in the materials sustainable supply chain field. It is found that this process can be fully efficient and sustainable in the building transportation system. At the same time, this process cycle is also more suitable for construction waste management, so we propose Construction Waste Management Framework (CWMF) in-depth research through the analogy SICS. CWMF efficient, economical, and sustainable disposal of construction waste to achieve sustainable development.

Keywords: SICS, CWMF, Construction Waste Management, Framework, Case Study, Analogy Sustainable Development.

1 INTRODUCTION

Globally, the building sector's sustainable development is receiving greater and more attention (Alhawamdeh, 2022). While the construction industry is considered a pillar industry for the realization of the built environment, it is also the main culprit for environmental pollution caused by the production of a large amount of waste (Bao,2019). Large-scale building, remodeling, and demolition projects have generated enormous amounts of waste due to the recent decades' fast urbanization of the world (Alhawamdeh, 2022). Construction is regarded as the leading producer of solid trash, contributing 36% of all waste generated globally, or 2.5 to 3.5 billion tons of emissions yearly. (International Solid Waste Association (ISWA,2015). This presents a considerable obstacle to the building industry's ongoing growth. (Bakshan et al., 2015). However, the current approach to the disposal of construction waste is generally stuck in the primary stage, facing the problems of being time-consuming, high human cost, and incomplete treatment. Therefore, the digital technology that can help deal with construction waste today should be improved. At the International Housing Forum on sustainable urban development, the Singapore Housing & Development Board (HDB) and the Nanyang Technological University, Singapore (NTU Singapore) signed a new research and development agreement about the SICS（Bhunia, 2017）.SICS seeks to use digital technologies to convey building materials effectively and responsibly, which could realize smart building raw material transportation. Since waste disposal is usually like raw material disposal processes, this system process can be widely used in construction waste treatment. In the past few decades, China's urbanization process has been accelerating. A variety of new, demolition and excavation projects increased. A large amount of engineering waste, waste generated in the construction stage, demolition waste generated by the reconstruction of the old city, and decoration waste, resulting in a large increase in the amount of urban construction waste(Hao *et al.*, 2021). This paper discusses construction waste disposal in Singapore based on SICS. Based on the application of SICS in the supply chain of intelligent building materials in Singapore, this paper analyzes the key process of the system and combines the similar characteristics of construction waste management and construction materials supply chain to establish CWMF. The results of the study provide a model for the efficient, economical, recyclable, and sustainable disposal of construction waste and provide a framework for future waste management. At the same time, this study is intended to provide a model method for the treatment of construction waste in China.

The organizational structure of this paper is as follows. The second part introduces construction waste management in Singapore and its technical shortcomings. The third part describes five steps of the application of SICS system in the field of building materials. The fourth part is establishing CWMF, using SICS's application in construction waste recovery. Finally, the paper summarizes and gives suggestions based on the current situation of construction waste in China.

2 SINGAPORE CONSTRUCTION WASTE MANAGEMENT

Singapore's territorial resources are limited, with only about 719.1 square kilometers (World Population Review, 2019). Construction waste accounted for 18% (1,013 tons) of waste distribution in 2021 (National Environment Agency, 2021). If the construction waste disposal problem is not solved properly, it may occupy a large area of land resources, affecting environmental quality, economic development, and residents' quality of life (Fig.1).

The strategic management of construction waste is essential to achieve a higher level of resource efficiency. Therefore, Singapore has issued some environmental policies to solve the construction waste disposal problem. Singapore has added the relevant content of construction waste disposal to the practice regulations of registered structural engineers and registered building contractors, requiring practitioners to comply with the regulations and control the reduction of construction waste in actual construction projects. In addition, in 2008, the Building and Construction Authority of Singapore issued the Building Control Act and implemented the Building Control Ordinance, which stipulates sustainable standards for construction waste (Wang et al, 2020).

After years of efforts, Singapore is making some progress on the local construction waste problem. With the development of digitization, artificial intelligence, and the Internet, intelligent technology is applied to design, construction, urbanization, and so on. However, how can intelligent technology help people reduce the cost of construction waste disposal, reduce workforce and material resources, and accurately and efficiently recycle and use construction waste remains to be developed.

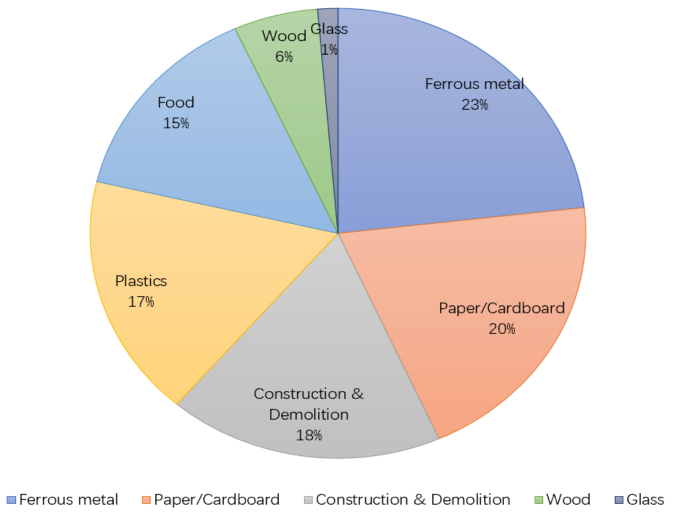

Fig.1. 2011 Waste Distribution in Singapore (National Environment Agency, 2021)

3 METHODOLOGY

This paper conducted a case study and analogy to investigate the accurate and efficient recycling of construction waste through intelligent technology. Expect intuitive analysis and derivation from the analogical application of SICS to the processing and recycling of construction waste. A case study is a detailed study of a specific subject, which is a suitable study strategy when researchers want to learn precise, contextual, in-depth information on a certain real-world topic (McCombes. ,2019). An analogy is a comparison of two things, or systems of things, that focuses on the similarities between them (Stanford Encyclopedia of Philosophy, 2019). Investigate the supply chain in construction projects based on literature reading and related information collation. Using SICS as a case study, find the similarity between the building materials supply and waste disposal processes. Next, CWMF is conceived by analogy with SICS. Then, combined with the actual construction waste processing, CWMF is established. In addition, according to the advantages and characteristics of CWMF, the research will promote this framework in China (Fig.2).

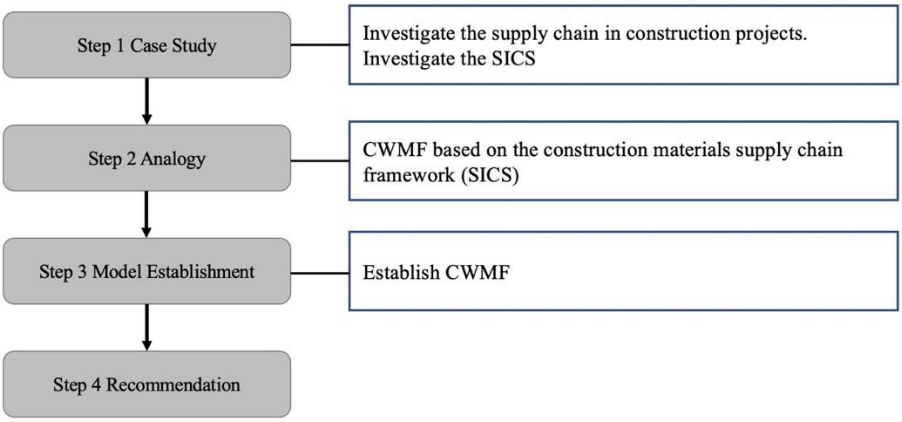

Fig.2. Research methodology procedure

4 CASE STUDY

The SICS consists of three main components: IBIS, Smart tracking System, and Smart Crane System (Bhunia,2017). IBIS is the central digital database that serves as a workspace for collaboration. The use of 3D models of HDB projects as a common platform enables stakeholders to log in with real-time information and progress updates on the project from their dispersed locations. Smart Tracking System will virtually manage the logistics of construction inventory. Smart sensors with geo-tagging capabilities will be attached to building components to avoid misdelivery. The Smart Crane System improves the safety of construction work by calculating safe lifting paths through intelligent sensors embedded in building elements and a network of sensors around the construction site (Fig.3).

SICS revolves around IBIS, the first step of which is the integrated production of the materials needed for the construction process. The second and third steps are part of the Smart Tracking System. The second step uses Radio Frequency Identification (RFID) technology to track information and the real-time location of the products. The main components of an RFID system are a reader and multiple tags. Each tag has a unique ID, and the reader interrogates tags through communication over a shared wireless channel real-time shopfloor production data(Lai *et al.*, 2022). The third step is the synchronization of logistics information during the transport of goods, including the correspondence between goods and vehicles to avoid loss of or damage to goods in transit and to monitor that goods arrive on time at the construction site and are stored as planned. The fourth step belongs to the Smart Crane System, which interacts with building information modeling (BIM) to achieve real-time construction progress tracking. visualizes the location information of the lifted object and a tower crane, acquired from the sensors installed at the tower crane, and the surroundings of a building in real time(Guo *et al.*, 2022). This reduces the need for manpower, avoids duplication of work due to incorrect lifting, and reduces energy waste. The fifth step is the integrated production scheduling based on the 3D model information of the building, the completion of the building construction, and the availability of materials.

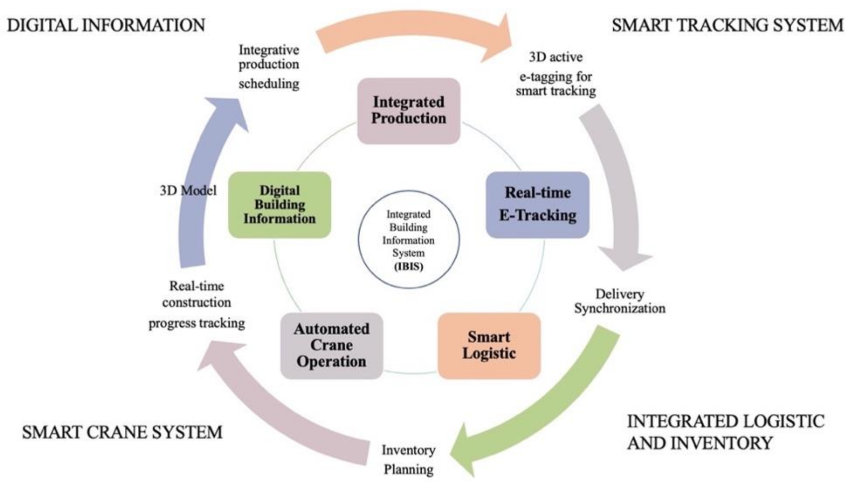

Fig.3. Smart Integrated Construction System Framework

5 CONSTRUCTION WASTE MANAGEMENT FRAMEWORK BASED ON SICS

CWMF applies the construction materials supply chain SICS to the process of recycling construction waste (Fig.4). In the first step, a BIM model is used to calculate the amount of construction waste generated in real-time during the construction phase and its source, and the information about the construction waste is sent to the database behind the RFID. In the second step, RFID tags containing material information are attached to the corresponding construction waste. The construction waste is located and monitored in real-time to avoid environmental pollution caused by unreasonable discarding. The third step is to classify the construction waste according to the database established at the front end and decide on the waste disposal method. This database needs to cover when the construction waste was generated, the type of structure, the different sources, the utilization value, etc., ultimately forming a three-dimensional traceable multi-dimensional database. The first method of construction waste disposal is reuse, it is beneficial and necessary to reuse waste concrete as recycled concrete aggregate for new concrete is seen as key to the sustainability of the construction industry in a circular economy(Robayo-Salazar, Valencia-Saavedra and Mejía de Gutiérrez, 2022).In addition, the use of bacteria as a restorative agent can give concrete the ability to self-heal(Saleem *et al.*, 2021). The second method is recycled, whereby the waste concrete is transported to a power station for incineration to generate electricity or to a nearby site for backfilling of the pit, or the waste formwork is converted into a rubbish bin or flower bed. Solid waste incineration is an effective waste-to-energy method and is currently a well-controlled technology(Tan *et al.*, 2022). The third option is to clean and dispose of poor-quality construction waste that cannot be used for reuse or recycling and then landfill it. The construction waste is sorted, and the materials are stored according to their category. The fourth step is the automated crane operation, which uses sensors and automated crane interaction to monitor the loading in real-time, reducing the need for manpower and avoiding transport problems caused by loading errors. Information is also synchronized in real-time during transport to plan a rational and low-energy consumption transport route and obtain accurate arrival times. The fifth step is to collect different digital factory information, including information on the location of the factory, the type of waste it can accept, and the amount of waste it can hold. The factory information will be sent to the construction site for planning the transport destination and route, and to various stakeholders such as resource management and planning authorities, government, power plants, backfill plants, raw material plants, etc.

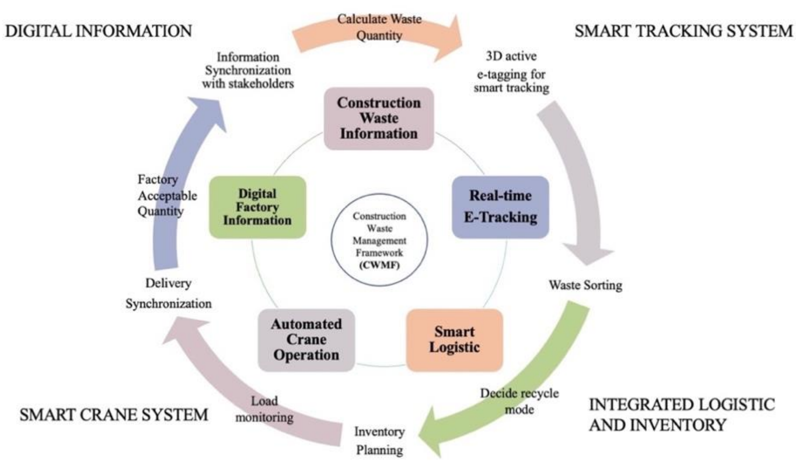

Fig.4. Construction Waste Management Framework

5. CONCLUSION

In conclusion, optimizing the whole process of SICS is suitable for construction waste processing. This paper uses RFID in SICS for reference, which is helpful for real-time monitoring of construction waste. Synchronizing logistics information in SICS and clarifying the relationship between responsibility and authority plays an excellent role in garbage sorting. Smart Crane System reduces workforce demand, reduces energy waste, and helps to rationally plan transportation with low energy consumption and high efficiency in waste treatment. Therefore, the CWMF has its reasonableness. It can also realize the sustainability and regeneration in the whole process of construction waste treatment and realize the efficient synchronization of information. Facing the increasingly severe pressure of construction waste, further research and application of the CWMF framework in the field of construction waste in China should be conducted based on the current situation of construction waste treatment in China. Establish a CWMF framework for efficient, economical, accurate, and sustainable construction waste treatment.

6. REFERENCES

Alhawamdeh, M. and Lee, A. (2021) ‘Construction Waste Minimization: A Narrative Review’, The International Journal of Environmental Sustainability, 18(1), pp. 1–33.

Bao, Z.H. et al. (2019) ‘Procurement innovation for a circular economy of construction and demolition waste: Lessons learned from Suzhou, China’, Journal of Waste Management, 99, pp. 12-21.

Bartha, P. (2022). ‘Analogy and Analogical Reasoning’, The Stanford Encyclopedia of Philosophy (Summer 2022 Edition), Edward N. Zalta (ed.).

Bhunia, P. 2017. HDB Singapore partners with local universities to leverage big data and smart technology in planning, designing, and building public housing.

Guo, H. et al. (2022) ‘Automated Selection and Localization of Mobile Cranes in Construction Planning’, Buildings, 12(5), p. 580.

Hao, J. et al. (2021) ‘Quantifying construction waste reduction through the application of prefabrication: a case study in Anhui, China’, Environmental Science and Pollution Research, 28(19), pp. 24499–24510.

ISWA (International Solid Waste Association). 2015. ISWA Report 2015. Working Together Towards a Cleaner, Healthier Planet.

Lai, Y.-C. et al. (2022) ‘A Bit-Tracking Knowledge-Based Query Tree for RFID Tag Identification in IoT Systems’, Sensors, 22(9), p. 3323.

McCombes, S. (2023). ‘What Is a Case Study? | Definition, Examples & Methods.’, from https://www.scribbr.com/methodology/case-study/

National Environment Agency. (2021). Waste management. Retrieved October 10, 2021

Robayo-Salazar, R., Valencia-Saavedra, W. and Mejía de Gutiérrez, R. (2022) 'Reuse of Powders and Recycled Aggregates from Mixed Construction and Demolition Waste in Alkali-Activated Materials and Precast Concrete Units', Sustainability, 14(15), p. 9685.

Saleem, B. et al. (2021) 'Performance evaluation of bacterial self-healing rigid pavement by incorporating recycled brick aggregate', Cement and Concrete Composites, 117, p. 103914.

Singapore Population 2019. Retrieved July 9, 2019, from: World Population Review.

Tan, J. et al. (2022) 'Co-disposal of construction and demolition waste (CDW) and municipal solid waste incineration fly ash (MSWI FA) through geopolymer technology', Journal of Cleaner Production, 362, p. 132502.

Wang, L. Chen, Y & Fu, K. (2020) 'Experience Research and Reference of Construction Waste Management in Singapore', China Environmental Protection Industry, (2), pp. 40–42.