Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268
e-ISSN: 2395-3454

Vol. 17 | No. 3 | pp. 1035-1041 | 2018

Original Research Paper

Open Access

Types of Environmental Pollution Caused by Real Estate Construction Projects and their Control Measures

Guihong Liu
Sichuan University Jincheng College, Chengdu, 611731, China

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 17-06-2018
Accepted: 03-08-2018

Key Words:
Real estate
Construction projects
Environmental pollution
Control measures

ABSTRACT

China's increasing urbanization rate and urban population, and the pace of renewal methods for old cities, have increased the demand for real estate construction projects. However, during construction, real estate constructions inevitably produce considerable amounts of waste gas, wastewater, solid waste, dust, and noise, which causes pollution and damages the environment. To further analyze the types of environmental pollution caused by real estate construction projects and their corresponding control measures, this study conducts a literature review on the differences between the environmental management schemes of developed and developing countries. Then, the types are summarized and their causes are analyzed. Results show that the real estate industry players in developed countries are relatively mature because they value environmental protection and assessment of real estate construction projects. Real estate construction projects cause four aspects pollution, namely, water, air, noise, and solid waste pollution. Polluted water is discharged without disposal, construction dust freely spread, and noise pollution is not effectively controlled, and they collectively result in environmental pollution. This paper also proposes effective measures to reduce noise pollution, strengthen air pollution monitoring, treat wastewater and solid waste generated by real estate projects, and improve environmental awareness and civilized construction awareness among workers. Our research results have important reference value in terms of the following: uniqueness of the environmental pollution caused by real estate construction projects; control measures on the energy consumption of the real estate industry; and environmental burdens and corresponding prevention mechanisms in the construction industry and promote the coordinated development of real estate construction and environmental protection.

INTRODUCTION

In recent years, China's urbanization and improved living standards have increased the demands for residential and commercial real estate. To meet these needs, China's new real estate projects, companies, and investments have since increased (Fig. 1). The expansion of cities and the renewal of old urban areas have also grown. Real estate projects have promoted urbanization, but the resultant environmental protection problems have also become prominent. Environmental pollution and ecological damages have caused irreparable losses, and they are thus regarded a major problem in China from the viewpoint of national economic and social development. It is practical to determine ways to combat environmental problems arising from various construction projects, analyze and evaluate the actual environmental impact of various stages of construction in China at the current stage, and take measures to reduce or eliminate various environmental pollutions to restore ecological losses.

Domestic real estate project construction uniquely affects the environment. Compared with traditional industrial projects, no obvious pollution exists in real estate projects. Then, compared with oil and mining projects, the impact of real estate projects are not directly observable in the local ecological environment. The environmental impact caused by real estate development projects may be comprehensive, that is, they involve water, air, noise, solid waste, and light pollutions and have wide ecological influence. Therefore, in this research, the types of environmental pollution caused by real estate construction projects are identified, and then the corresponding control measures are proposed. Scientific and reasonable classification of various pollution sources and their and control measures can effectively reduce the adverse impact of construction projects. Moreover, the experience of project implementers in handling real estate projects in large cities can serve as an indispensable theoretical and practical guide in ensuring the physical and mental health of the public, protection and improvement of the natural environment, and long-term economic and social development.

EARLIER STUDIES

With regard to environmental pollution, many foreign scholars have stressed that real estate construction projects and

their control measures are centered on people, fully consider the interaction between projects and the environment, and recognize the importance of ecological protection. In terms of environmental pollution caused by real estate construction projects, Cole et al. (1992) outlined the key issues related to the environmental assessment of material production and usage and listed four comparable commercial building components with similar thermal resistance and air pollution audit examples of energy. Malmqvist et al. (2009) analyzed the environmental efficiency of residential buildings, considering that energy use and indoor environmental quality of real estate construction projects should be stressed. Assefa et al. (2010) adopted the Eco Effect tool to compare the environmental efficiency of building performance. Scheuer et al. (2003) conducted an energy study of a building on the University of Michigan and showed that the production of building materials, transportation to site, and construction account for 2.2% of the primary energy consumption of the energy life cycle. Balaras et al. (2005) analyzed the heating energy consumption of European apartment buildings and their environmental impact. Simons et al. (2006) conducted a meta-analysis of the impact of environmental pollution on the value of residential real estate. Tam et al. (2006) proposed an environmental performance measurement indicator system for the construction process. Zhang et al. (2008) proposed a method to assess the environmental impact of dust emissions during construction and measured the health damage caused by building dust pollution. Zheng et al. (2014) studied the exogenous changes of urban air pollution and analyzed the impact of local air pollution on real estate.

In terms of environmental management and control of real estate construction projects, Cole (1998) reported that building environmental assessment has become the practice since the early 1990s, from which a number of issues, such as sustainability, life cycle assessment (LCA), globalization, and standardization, have been identified. Beerepoot & Beerepoot (2007) used data from the energy performance regulation measures of the Dutch residential construction industry and established the impact of government energy management policies on the construction industry. Revell & Blackburn (2007) reported that owners of small companies in the United Kingdom perceive environmental protection measures as costly and thus resist voluntary improvement of their environmental performance. The government's monitoring policies can effectively promote small-company ownership to benefit environmental governance. Testa et al. (2011) selected the building industry in certain areas in the European Union to analyze the impact of environmental regulation on corporate competitiveness. Kumar (2013) explored the impact of various environmental protection and construction regulations on housing protection in hilly towns and suggested new environmental protection regulations. Arvizu-Piña & Burgos (2017) stressed the necessity of establishing a knowledge platform to support the LCAs of the construction industry in emerging economies, considering that tight cooperation of the government, academe, and stakeholders is needed. The existing literature has shown that the real estate industry in developed countries is relatively mature because environmental protection during real estate construction is ensured by establishing third-party environmental impact assessment (EIA) agencies. Moreover, the application and development of EIAs in particular are also relatively mature. Given the booming real estate industry in recent years, the EIAs of real estate project holders have also received much attention. In these EIAs, the people's requirements on the living environment have become stringent; however, most of the measures related to environmental pollution and control of real estate construction projects remain at the theoretical level. This gap implies EIA-related research and application are long overdue.

In this paper, the types of environmental pollution caused by real estate construction projects are summarized. Then, the specific control measures to promote the rational layout of real estate projects and reduce their pollution and ecological damage are identified. This paper may serve as future reference for the EIAs of environmental pollution caused by real estate.

TYPES OF ENVIRONMENTAL POLLUTION CAUSED BY REAL ESTATE CONSTRUCTION PROJECTS

Water pollution: The main sources of water pollution caused by real estate construction projects are construction machinery for operators, wastewater for washing vehicles, and domestic wastewater. If not properly treated, then they will pollute surface water and groundwater systems in the surrounding areas. A poorly managed sewage discharge by workers at the construction site, especially the discharge of construction machinery and vehicle washing wastewater, increases the difficulty of collection and processing. The main pollutants in domestic sewage and catering wastewater from construction workers include oil, paints scrubber, and suspended solids, which are mainly organic substances. Construction machinery, washing wastewater, and permeate water generated from underground excavation may also exist, and they contain suspended solids, such as sand, mud, and mineral oil. Stacked building materials may be damaged by rainwater, and the main pollution in water is in the form of suspension.

Air pollution: Atmospheric pollutants generated during the construction phase of real estate projects include dust and exhaust gas generated by diesel machinery and other con-

Table 1: China's major noise monitoring environmental standards.

Serial number	Standard name	Standard number
1	Environmental quality standard for noise	GB3096-2008
2	Environmental noise emission standards for industrial enterprises	GB12348-2008
3	Noise emission standards for social life	GB22337-2008

struction machinery and equipment, transportation and driving vehicles, and burnt fuel by construction workers as a part of their daily living needs. The pollution factors include sulfur dioxide, carbon monoxide, nitrogen oxides, and hydrocarbons. A construction site is relatively spacious and wide. Hence, the time and discharge location of exhaust gas emissions are relatively dispersed, and the exhaust gas can be diluted and diffused in time, which prevent them from bringing serious adverse impact to the environment. Dust emission is the top priority in air pollution reduction at the construction site. During the construction stage, dust is formed when workers conduct earthwork, piling works, pipe network wiring, and road construction. Dust is also generated by wind power, cement, sand, gravel, and other construction materials during loading, unloading, transporting, and storing, as well as by the cleaning of construction work surface and solid waste, the running of construction machinery and transport vehicle (agitated and transport vehicle), and the cleaning of construction garbage. The dust generated during the construction of real estate is unorganized and mainly diffuses to the respiratory layer, and it has a huge impact on the surrounding atmosphere in sunny, dry, and windy weather. Dust damages the urban landscape and result in low visibility and serious traffic disruption.

Noise pollution: The main noise sources of urban real estate projects include underground garage-induced draft fans, heat exchange stations, water supply pump block, catering industry fans, and cooling towers. These noise sources continue to run for a long time. Located close to residential areas, they are likely to cause noise exceeding or reaching the standard of disturbance (Table 1). In general, the main equipment sources of noise are cooling towers, fans, and water pumps. The noise source of real estate projects is generally composed of the abovementioned noise sources. However, integrated noise represents a certain complexity spectrum that is difficult to manage. These noise sources do not only spread in air but also spread through the ground, walls, pipes, columns, and other building structures. Such noise is prone to vibration. Low-frequency noise has a large wavelength, and a wavelength that is close to the spatial size of the building easily causes resonance between a wall and an object. This feature causes fixed equipment to produce noise pollution, which is likely to exceed emission standards, and thus has certain impact on people, especially the elderly. Excessive noise aggravates residents and causes physical and psychological discomfort.

Solid waste pollution: Solid waste mainly comes from construction waste generated by the construction of real estate projects and the domestic garbage of construction site workers. Construction waste includes abandoned building materials, such as sandstone, waste brick, concrete, lime, earth, and stone from foundation works, land excavation, pipeline laying, and material transportation during construction. Construction waste generated in the workplace, such as scraps, waste materials, discarded bricks, and concrete blocks, is generally inorganic. However, a small amount of organic wastes, such as waste plastics, exhaust gas of paint, foam board, and packaging materials, are also generated. At the decoration stage, generated paint, plywood, enamel, and other garbage will not rot and deteriorate and thus difficult to dissolve. If not handled properly, then the landscape and environmental quality of the project will be greatly reduced. Domestic garbage is also an important source of solid waste. Real estate construction takes a relatively long time. The daily life of many workers on the site will inevitably involve the production of a certain amount of domestic garbage, mainly leftovers and feces. If left piled at the construction site or if not treated in time, then the domestic wastes can easily lead to the decay of pollutants with stinking odors and breeding cockroach pests. These scenarios seriously affect the landscape of the real estate project and the local atmospheric environment, and even cause certain infectious diseases that can endanger the health of workers.

CAUSES OF ENVIRONMENTAL POLLUTION OF REAL ESTATE CONSTRUCTION PROJECTS

Direct discharge of contaminated water and without proper disposal: During real estate construction, construction water and domestic sewage are not treated; if ever they are treated, they are conducted not according to standards. Within a short period, a huge amount of pollutants invades the tap water intake in downstream areas, which are likely to pollute drinking water sources. The current policies on the total control of discharge rights have not been strictly implemented, thus resulting in the lack of an established system for the total discharge control of real estate con-

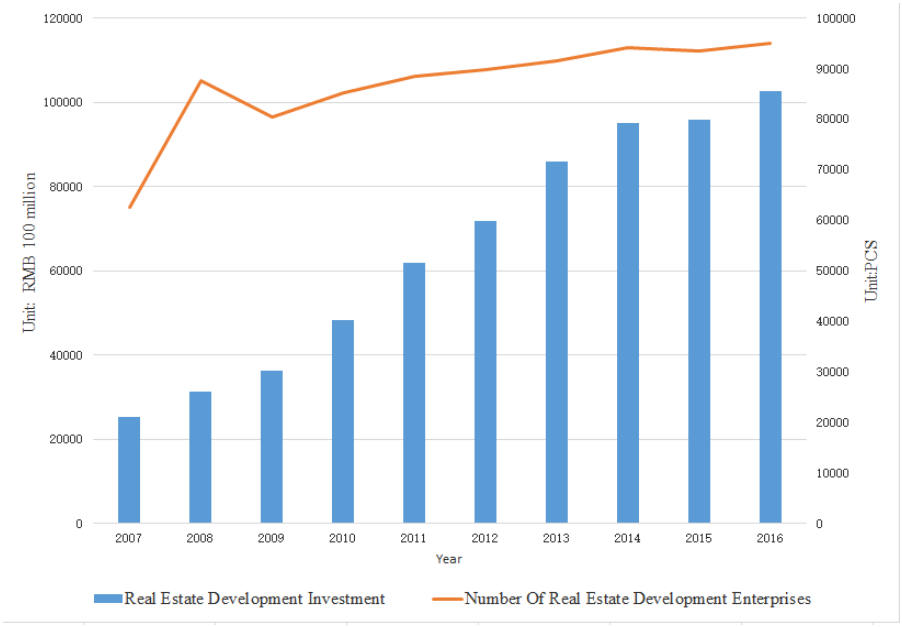

Fig. 1: China's real estate development investment and development enterprises from 2007 to 2016.
(Data from the National Bureau of Statistics of the People's Republic of China (http://data.stats.gov.cn/index.htm))

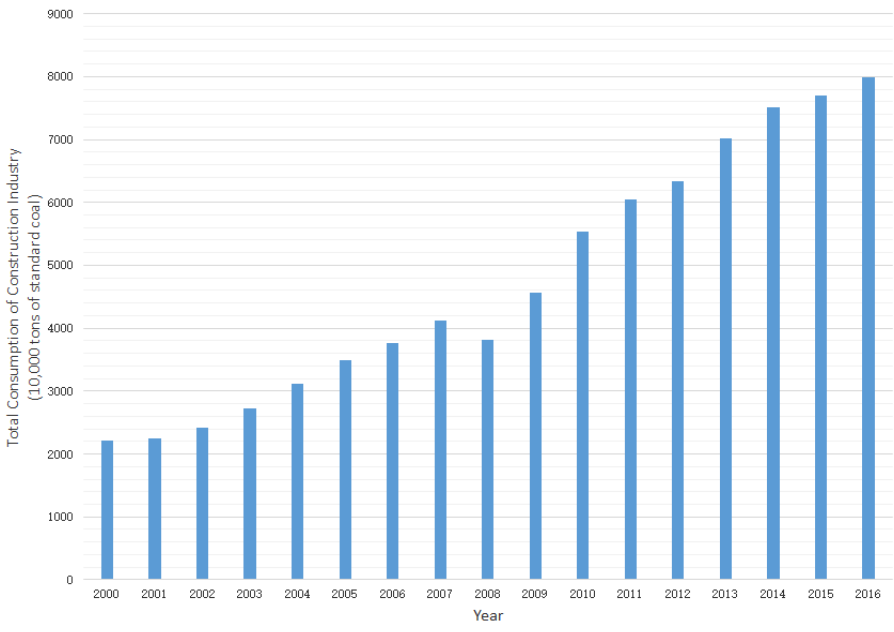

Fig. 2: Total consumption of construction industry from 2000 to 2016.
(Data from China Statistical Yearbook (2017-2001)).

struction enterprises. A legislative basis for the emission trading institution is largely neglected. Several problems, such as information asymmetry and constant changes, occur in practice. Hence, real estate construction enterprises practice proper drainage without approval and without knowing the benefits. In addition, due to financial limitations, many urban sewage treatment facilities where real estate construction projects are located seldom operate optimally.

Thus, some sewage is not treated, while others are directly discharged into rivers. Moreover, some sewage treatment plants are idle or encounter problems related to efficient sewage treatment (i.e., combined flow of rain and sewage in pipe networks).

Construction dust freely dispersed: The total energy consumption of China's real estate construction industry has increased annually, as shown in Fig. 2. However, some construction enterprises only pay attention to construction period and safety, but seldom on environmental protection. Some cities have introduced policies to control air pollution and improve air quality, in which the requirements and regulations have been clearly set for dust pollution reduction during urban development, such as when constructing fences, using dust shed and earth carrying with fully enclosed vehicles, cleaning transport vehicles before reaching the work site, and preventing dregs from running and leaking. However, the construction project holders often focus on the economic benefits only, and their environmental protection awareness is notably weak. In addition, necessary and powerful supervision is generally lacking. Building dust prevention is closely related to urban environmental management, urban infrastructure construction, and ecological construction, which involve many organizational functions, such as urban construction, municipal administration, sanitation, gardening, and environmental protection. Hence, task delegation and unified action among government bodies are necessary. At present, many city governments lack effective dust pollution control mechanisms and cannot clearly specify the responsibilities and rights related to prevention and control. These problems further lead to weak supervision, blame tossing, and inaction. In such cases, the absence of urban dust control measures and their methods for implementation becomes apparent.

Noise pollution is not effectively controlled: Some construction enterprises have insufficient understanding of noise pollution hazards, relevant legal knowledge, and awareness on noise pollution prevention. In daily management, some construction enterprises attach more importance to construction safety, project quality, and project progress over noise pollution prevention. The pollution status and construction arrangements in many cities are unscientific. It is often impossible to complete the construction tasks for the day before 22.00 pm, causing construction delays and affecting the nearby communities. The location of some real estate construction projects is also unreasonable. High-intensity noise pollution needs to be placed far from residential areas. Project holders are often reluctant to invest capital and manpower for the prevention and control of noise pollution. Necessary noise reduction barriers are not set to reduce noise. At the same time, the construction site does not manage the construction workers well, as some of them speak loudly, and the whistles of vehicles affect the lives of nearby residents.

CONTROL MEASURES TO ALLEVIATE ENVIRONMENTAL POLLUTION BY REAL ESTATE CONSTRUCTION PROJECTS

Promote the application of cleaner production in real estate construction projects: The government should provide necessary macro guidance for the application of clean production. Clean production is closely related with industrial self-discipline. If real estate enterprises can carry out industrial self-discipline and develop construction projects to protect the environment, then clean production can be easily achieved. However, in the current situation in which enterprises focus on profits, the lack of macro guidance and requirements from the government and the limited application of clean production ideas will only aggravate the environment pollution issue. The government should institutionalize EIAs for clean production and endorse these tasks to relevant functional departments in the real estate industry by following scientific processes of the work and by disseminating relevant documents. Under the guidance and supervision of EIA teams, the government must not only take action by identifying legal responsibilities, but also by informing the public about the EIA results from the perspective of information disclosure, establish social supervision, enable real estate development enterprises to promptly publicize their EIA indexes, and expand social influence by applying cleaner production in the real estate industry. These actions will likely encourage enterprises to regulate their production behavior. Consequently, clean production may be implemented the soonest time possible, and healthy and orderly production environments will be systematized.

Effectively reduce noise pollution: A number of construction equipment is used during real estate construction projects, but they are regarded as strong noise sources. Increased noise levels from multi-noise sources can be superimposed. Therefore, at the different construction stages, the construction noise should be limited on the basis of what is only allowed in construction sites (GB12523-1990). For example, the masonry of surrounding walls can be completed before onsite construction, and a noise-reducing safety curtain can be installed in advance adjacent to the location of sensitive-noise protection target. Strengthening the control of man-made noise, eliminating artificial knocking and loud noise, and enhancing the consciousness of all construction workers also prevent noise. During construction, the construction personnel can actively control the noise generated by template removal and the loading and unloading of substances. The construction site layout needs

to be designed reasonably, and the mechanical equipment that generates high noise are placed away from the protection target. Low-noise machinery or construction machinery with noise-reducing equipment are preferred. Pile-based construction should give priority to new and environmentally friendly methods of pre-stressed static pressure pipe piles. Bored piles should be equipped with environmentally friendly construction equipment such as rotary drilling rigs. Mechanical equipment with high noise should be equipped with a closed mechanical shed to reduce noise impact. The use of commercial concrete needs to be promoted to avoid concrete mixer noise. The inspection, repair, and maintenance of construction machinery should be strengthened to avoid abnormal noise pollution caused by mechanical failure. Noisy construction equipment should be used at different times as much as possible. Noise monitoring at the construction site should be regularly conducted, and noise control measures should be adjusted according to the monitored situation to ensure its effectiveness and avoid disturbing people.

Strengthening the monitoring of air pollution: A well-organized construction organization can bring about "twice the result with half the effort" for construction enterprises. Scientific analysis and research on the sequence, stage, and quantity of excavation before construction can be implemented by carefully organizing and optimally using the excavated earthwork for backfilling and by reducing the quantity of earth transport and return shipments, thereby reducing atmospheric pollution. The construction area layout and a reasonable route scheme for abandoned soil transport can lessen the distance of earthwork conveyance. Transportation routes also need to be improved, and personnel and equipment resources should be allocated to regularly spray water to reduce dust emission. The covering or stacking in the fixed facilities should be ensured for the piled earthwork on site because powder piles may generate dust. Dust removal facilities, such as bag filters and spray precipitators, must be installed in the cement tanks and mixing stations used at the site. Strict management of transport vehicles should be adopted, such that vehicles can detect exhaust gas, are not overloaded, do not exceed the sideboard when transporting bulk building materials, and can adopt effective concealing measures. At the same time, vehicle sideboards and wheels should be washed before arriving at the site to prevent vehicle spilling and entrainment. Construction of high-rise buildings have dedicated floor garbage transportation passages. Outer facades of buildings are installed with dense mesh safety nets to reduce wind speed within buildings and prevent dust from entering the surrounding environment. New processes and technologies can be used to shorten the construction period while achieving environmental protection. Mechanical equipment maintenance can be adopted, and particulate matter emissions in flue gas can be reduced. Tea and large stoves used on site can be equipped with smoke- and dust-removing mechanisms or clean energy, such as the use of electricity and liquefied gas.

Dispose wastewater and solid waste generated by the project: Wastewater from real estate construction collected by sedimentation tanks, as well as domestic sewage, is treated by sewage treatment plant and discharged into the municipal sewage pipe network. Discharging directly into rainwater pipe network, urban sewers, and rivers is strictly prohibited. The fuel, engine oil, and lubricating oil used in various types of vehicles and equipment should be monitored. All discarded oils require centralized disposal and should not be dumped or discharged into municipal rainwater pipe networks and nearby rivers. Real estate construction projects produce considerable waste. Abandoned, unkempt, or improperly disposed building materials can be washed away and drained in bodies of water, which result in water pollution. Departments who regulate construction projects should institutionalize measures with regard to the transportation and piling of construction waste along roads. After construction has been completed, excess or abandoned construction materials are removed. Temporary sheds and buildings are demolished to restore the natural landscape. Domestic garbage should be concentrated in a garbage pool for timely transportation, and the waste generated by woodworkers, electricians, welders, steel workers, and painters should be comprehensively utilized and segregated and not abandoned after construction.

Improve the environmental and civilized construction awareness of construction workers: The environmental awareness of construction workers should be enhanced. Construction workers should have a strong sense of environmental protection and encouraged to fully understand related state laws and regulations. Onsite construction processes need to be orderly and systematic, including onsite enclosure, closed management, construction site sanitation, material stacking, onsite accommodation, onsite fire prevention, comprehensive public security management, construction signage, and management of living facilities. Construction site management, material and quality management, and strict control of waste discharge should be strengthened. In essence, everyone should take action, even if environmental protection highly depends on management (i.e., management ensures efficiency). Building construction shall be submitted to municipal and district environmental protection departments following the required standards prior project commencement. With regard to concentrated areas of noise-sensitive buildings in urban areas, con-

struction is prohibited at night, except for repairs, rescue operations, and continuous operation due to production process requirements or special needs. At the same time, environmental pollution complaint reception systems should be established. The receiving staff should be oriented on how to keep detailed records of issues raised by relevant parties, and they should respond within a certain period.

CONCLUSION

The construction industry in China will continue to rapidly develop as urbanization advances. However, the development of the construction industry will face more severe energy crisis and environmental pressure due to limited resources and the urgency of ecological protection. Environmental pollution caused by construction is one of the key issues in China. This paper compares and analyzes the differences between developed and developing countries in terms of their environmental management and control measures in real estate construction. Then, the types of environmental pollution caused by real estate construction projects are summarized and the reasons are analyzed. The results show that the real estate industry in developed countries greatly values environmental protection and EIAs of construction projects. Water, air, noise, and solid waste pollution are the main types of environmental pollution caused by real estate construction projects. The direct discharge of sewage, unhampered spreading of construction dust, and lack of effective noise pollution control measures are the important factors of environmental pollution caused by real estate. These problems can be solved by effectively reducing noise pollution, strengthening the monitoring of air pollution, treating water and solid waste generated by the project, and improving environmental awareness and orderly construction of workers. In the future, the environmental pollution assessment index system at the industry level should be enriched, the construction-environment evaluation method at the project level should be completed more scientifically, and a series of environmental monitoring (planning, design, construction, operation, and maintenance of real estate construction projects), optimization of construction site, and quality inspection should be continuously implemented and reviewed.

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