Integrated and effective platform governance mode for managing construction muck waste for a circular economy

Weiwei Wu
Southeast University
Youying Yin
Southeast University
Jian Li Hao (✉ JIANLI.HAO@xjtlu.edu.cn)
Xi'an Jiaotong-Liverpool University  https://orcid.org/0000-0003-3064-9794
Wenting Ma
Xi'an Jiaotong-Liverpool University
Guobin Gong
Xi'an Jiaotong-Liverpool University
Shiwang Yu
Xi'an Jiaotong-Liverpool University

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Abstract

Construction waste is a type of solid waste that is inevitably produced in the process of urban development and has a dreadful environmental impact due to inadequate management of it by the public sector. The purpose of this paper is therefore to investigate platform governance as an alternative strategy for muck waste management that will contribute to a circular economy. A comparison between the traditional governance process and platform governance of muck truck management is made by using Petri-net. Nanjing’s muck smart supervision platform is used as a case study to assess effectiveness of the platform governance mode. Results from Petri-net simulation modeling software reveal that the platform governance mode is more effective than the traditional mode. Based on the case study of Nanjing’s muck smart supervision platform, it is found that the success of Nanjing’s muck waste management can be attributed to the platform governance mode. This means that the platform management approach can contribute to the sustainability of muck waste governance.

It is feasible to utilize the platform governance mode for muck waste as an integrated and effective management mode for current practices of muck waste management and resource recovery in China. The platform governance mode can significantly improve the efficiency of muck waste management and provide economic and environmental benefits as part of a circular economy.

1. Introduction

With the rapid development of Chinese urbanization, the amount of construction and demolition (C&D) waste has been steadily increasing, requiring more integrated and effective management (Yu et al., 2022). Muck waste is a type of C&D waste that is generated from new construction, renovation, and demolition activities (Ma et al., 2022a). As a complex mixture, muck waste usually contains soil, gravel, wood chips and other materials (Wang et al., 2020). Generally, landfills and open waste dumps are the most common waste disposal measures and the most prominent pollution sources (Wijekoon et al., 2021). Without any treatment, large quantities of muck waste are transported to landfills by construction units, and even dumped in the process of transportation for the excessive pursuit of the economic benefits of muck truck drivers (Guo et al., 2020). On the one hand, piling up and dumping waste to landfills will occupy many land resources and result in environmental pollution (Hao et al., 2022), while the dust generated in the dumping process will cause serious air environment pollution. Therefore, the huge problem of muck waste management is becoming a critical environmental issue.

The presently operated linear economic models of muck waste disposal lead to the rapid consumption of natural resources, which accumulates waste and pollutes the environment (Hart, 2021). Alternatives to such models are those in the context of a circular economy (CE), which are C&D waste management practices that ensure that waste material flows in a closed loop (Mahpour, 2018; Guo et al., 2022). In production/distribution and consumption processes, the CE can be defined as an economic system that replaces the ‘end-of-life’ concept with the concept of reducing, reusing, recycling, and recovering materials (Kirchherr et al., 2017). A prerequisite for a CE is the development of an efficient waste management
system (Fedotkina et al., 2019). Thus, exploring how to establish an integrated and effective management system for muck waste in a CE is of great importance. Furthermore, the revolution in information and digital technology has been reshaping the global business environment, with a number of digital platforms emerging in different industries (Yi et al., 2019). Within the framework of a CE in the construction sector, a platform can be applied to provide an integrated and holistic approach for transparent, efficient, complete, and fast management of all phases implicated in public work planning (Luciano et al., 2021). Hence, exploring a platform as a governance mode might be a suitable way to construct an integrated and effective muck waste system in the context of the development of a sustainable construction industry and fulfilling the principles of a CE.

This paper contributes to the body of knowledge related to construction muck waste management and develops an integrated, effective, whole-process platform governance mode for the management of muck waste in a CE. The paper first provides a comprehensive review of muck waste management and the platform governance mode, it then explains muck waste management under the platform governance mode and describes the assessment of the muck waste management process. A case study in Nanjing is included to analyze the actual effect and benefit of the platform governance mode, and findings from the study are used to provide suggestions for future research.

2. Literature Review

2.1. Construction muck waste management

Waste management is a process that includes the collection, transportation, processing, recycling or disposal, and monitoring of waste materials (Lu et al., 2022). Since unsustainable waste management has the potential to cause various environmental problems (Hao et al., 2021), it is important to create an integrated and effective system for waste management (Abdul & Syafrudin, 2018; Ma et al., 2022b). Several previous studies have attempted to find a more effective method for muck waste management. Zhou used modern scientific and technological means to design a muck truck monitoring system, which was implemented by using the Internet of Things (IoT) and 3G networks to reduce muck waste management costs and build an integrate platform (Zhou, 2014); however, the research focused on the technological application, without analyzing the benefits from the perspective of public governance. Owing to the high costs and significant economic and social impacts, waste collection and transportation are crucial activities for an efficient waste management system (Mojtahedi et al., 2021). Guo. et al. (2020) optimized the route of transporting muck waste to reduce the risk of traffic accidents, while Wang (2021) presented effective evaluation methods and suggestions on route selection for muck truck transportation. Muck waste reuse or recycling in a circular economy has been discussed extensively by researchers, with several having investigated the possible applications of tunnel muck as a concrete aggregate alternative for roads and buildings (Riviera et al., 2014; Taqa et al., 2021). Marini & Bellopede (2013) analyzed the reuse of tunnel muck as industrial raw material, while Zhang et al. (2022) suggested that muck from slurry shield tunnels can be used as a growth medium to cultivate plants.
The literature review of muck waste management shows that little research has been done on the integrated whole-process management of muck waste management and public governance approaches that can be utilized for improving muck waste management.

2.2. Platform governance mode

In earlier studies, the platform concept was mostly used in the product development and technical component integration domains (Wu et al., 2022). The term “product platform” is a collective concept based on common product elements, including a set of designs and components shared by products (Meyer & Utterback, 1993). The purely technical perspective of “platform” gradually evolved into a form of organization in the business and innovation management domain (Facin et al., 2016). A platform can be defined as an intermediary role in two-sided or multi-sided markets (Rochet & Tirole, 2003; Rochet & Tirole, 2006). Platforms have become a new form of organization or a virtual reality space that can facilitate bilateral transactions and have obvious network externalities (Evans et al., 2014). In the digital economy era, platform-led digital industrial organization can promote the transformation of traditional resource allocation methods (Gao & Sun, 2022).

Recently, platforms have begun to receive attention in public sector research (Haveri & Anttiroiko, 2021). In the field of public administration, platform can be a governance tool or an organizational logic (Reid et al., 2015; Fedotkina et al., 2019). Janssen and Estevez (2013) proposed adopting the platform for public governance, innovating the way the government communicates with the public and other organizations, and providing help for government decision-making. Haveri and Anttirotko (2021) regarded platforms as a fourth governance mode and hybrids that incorporate features of the three basic modes of governance (networks, markets, and hierarchies). Meijer and Boon (2021) pointed out that digital platforms supported by information and communication technologies and rules of exchange can be used to create public value. Prior research suggested that platforms can participate in public governance as third parties and improve the traditional governance mode of the government through modern information technology owned by the platform itself (Wu et al., 2022). As mentioned by Ansell and Miura (2020), platforms might contribute to public governance and help the public sector mobilize unused resources and promote the sharing or reuse of resources. In addition, a considerable amount of literature on platform governance focuses on the development of smart city governance (Caprotti & Liu, 2020; Rehm et al., 2021; Repette et al., 2021). In these studies, the authors advocate establishing digital platforms driven by information and communication technology as governance tools for the sustainable development of cities.

The platform is not only a technological system and organizational model, but also an emergent governance mode that uses modern information and communication technology to innovate the governance mode and achieve the modernization of the capacity for governance. Based on the literature review of muck waste management and platform governance mode, it is clear that platform governance mode can provide an effective way to realize integrated and effective management of muck waste in a circular economy. However, the research and practice of platform as a governance tool for upgrading the muck truck management industry is still lacking. Therefore, this research sheds new light on investigating the feasibility of providing the platform governance mode for muck waste management as an integrated
and effective strategy, and building a muck waste management platform as an efficient waste management system.

3. Muck Waste Management Under The Platform Governance Mode

3.1 Definition of muck waste management platform

Analyzing the connotation of the term “platform” is a precondition for defining the concept of a “muck waste management platform”. In a two-sided market, platforms create value as intermediaries by connecting two different communities (Eisenmann et al., 2006). Platforms can improve the efficiency of the industry by building stable basic technology, allowing users to access a platform and produce diversified products and services (Ghazawneh & Henfridsson, 2013). In addition, digital platform is a unique form of platform organization. As a standardized digital interface, a digital platform can facilitate the interactions between parties, such as the sharing of digital resources and analytics-based information (Chen et al., 2022). In this paper, we combine the concept of economic platforms with the concept of digital platforms to define the muck waste management platform. The muck waste management platform refers to the use of modern information and communication technology to establish a digital platform to supervise the real-time dynamics of muck waste, collect various and tamper-resistant data during the transportation of muck waste, incentivize and restrict the transportation behaviors of muck truck drivers, and allow muck transportation and disposal enterprises to actively comply with the norms. The platform emphasizes the use of digital management methods to achieve information sharing among different platform participants, provide better muck waste management services, and receive a multitude of benefits emanating from integrated and effective management.

3.2. Characteristics of the platform governance mode for muck waste management

3.2.1. Participants

There are three main entities in the framework of platform governance for sustainable development: (1) administration represents all state actors and has the authority and mandate to guide, coordinate and manage the development process; (2) citizens are made up of citizens, enterprises and other nonstate actors; and (3) policy is a system that represents rules, regulations, incentives, networks, communities and other instruments, and is the means through which the administration steers, coordinates, and manages development actions (Janowski et al., 2018). From this perspective, the participants of muck waste management platform can be divided into three categories, including the public sector of muck waste management, relevant enterprises, and muck waste management policies.

In the platform governance mode, the role of the public sector is to empower platform enterprises to participate in muck waste management and create public value together. Relevant enterprises refer to platform enterprises and muck transportation and disposal enterprises. Platform enterprises are
responsible for the operation and management of muck waste management platform and collecting muck waste stream data in real time through modern information technology to eliminate information islands between them and the public sector and improve management efficiency. By processing and analyzing collected data through cloud computing, IoT and big data, the muck waste management platform can offer more integrated, efficient and smarter public governance services and ultimately promote sustainable development of muck waste management. Muck transportation and disposal enterprises are the subject of regulation and are required to join the muck waste management platform. Finally, muck waste management policies formulated by the public sector comprise standards, laws, regulations, and incentives for muck waste transportation, disposal and sweep.

### 3.2.2. Two-sided market structure

As shown in Fig. 1, in the operation process of the residue waste platform, the main participants are muck transportation and disposal enterprises and the public sector, which meet the conditions for bilateral users to participate. The platform governance mode redefines the role of the public sector from directly delivering public services to delivering public services through a muck waste management platform. The public sector clarifies the rights and obligations of the platform to participate in the management of muck waste treatment and provide a stable policy guarantee for the operation of the platform. As a third party, the platform enables the whole-process of the supervision of muck waste management to be implemented, steps up efforts in supervising the behaviors of muck transportation and disposal enterprises, and creates profits for the platform enterprise by providing data services. Hence, the public sector and muck transportation and disposal enterprises are different but interdependent user groups of the platform. As platforms bring together multiple user groups, they create network externalities (Janowski et al., 2018; Zhong et al., 2021). Platforms are based on the concept of indirect network externalities, which means that the number of users on one side of the platform affects the value of the platform to the users of the other side (Rochet & Tirole, 2006). The more the public sector collaborates with the muck waste management platform, the more efficient government services can be obtained by enterprises. Similarly, the more enterprises join the platform, the less offline governance power is invested by the public sector, and richer governance information can be obtained through the platform. As the scale of two-sided users grows, the platform exhibits economies of scale, reducing governance costs and enhancing users’ experience. For the purpose of reforming public sector governance, it is crucial for the platform to exploit network externalities and policies to lock in and attract more enterprises that are likely to evade regulation and illegally dump muck waste.

### 3.2.3. Value co-creation

Value co-creation is a dynamic process in which the subjects of value creation are interaction and resource integration (Zhong et al., 2021). Previous research has shown that the concept of co-creation is closely associated with the practice of platform and that platform governance can enable public value co-creation between citizens and administration (Janowski et al., 2018; Yu et al., 2019). Currently, the utilization of digital technologies in creating and appropriating value is an important characteristic of a
platform (Chen et al., 2022). A digital platform is not only a way to connect information and services, but also a way to engage different agencies for one target (Yu et al., 2019). The essence of value co-creation of the platform governance mode is that the platform has the capacity to promote interaction and cooperation between participants. In this study, value co-creation refers to the process of creating value jointly between participants of the platform through interaction and resource integration. In a bid to improve muck waste management, the public sector needs to cooperate with a platform enterprise to initiate and run the platform that coordinates and monitors muck transportation and disposal enterprises. Meanwhile, the public sector is responsible for offering an adequate policy environment to maintain cooperative relationships. The resource integration properties of platforms make it possible to significantly increase the ability to effectively solve problems of muck waste management, including muck waste stream data processing, automatic control instructions for muck transportation and disposal enterprises, and public sector decision making (Ryazanova, 2021). Through the platform's information services, it is more convenient for muck transportation and disposal enterprises to communicate with the public sector and regard each other as collaborators to ensure that the public sector fully considers the actual needs of enterprises when formulating relevant policies. Given this perspective, the platform governance mode is able to contribute to finding a solution for the problem of muck waste management and facilitate the co-creation of value.

3.3. Framework of the platform governance mode

Incorporating the above characteristics of the platform governance mode, this section proposes a framework for the platform governance mode to demonstrate the interactions between participants in the muck waste management system. The participants’ relationships underpin the platform governance mode for muck waste management and the framework is depicted in Fig. 2. The platform enterprise builds muck waste management platforms by integrating enterprises and the public sector in the waste management industry and guides the cooperation and information sharing of various stakeholders through policies.

4. Assessment Of The Muck Waste Management Process

4.1. Petri-net

Petri-net was invented by Carl Adam Petri and is a graphical tool for the description and analysis of concurrent processes (Petri & Reisig, 2008). It is very intuitive and is widely used in computer, mechanical manufacturing, automation and other business process modeling. As a mathematical tool, Petri-net allows dynamic simulation of concurrent and parallel systems with time constraints (Jing et al., 2013). Therefore, this paper uses Petri-net to build a platform governance model and traditional governance model of the muck waste management process. According to the actual situation of the governance mode of muck waste, we need to redefine the basic elements of the Petri-net, as shown below.

(1) Token. The token represents the resources contained in the place that can be passed within the system (Petri & Reisig, 2008). In muck waste management, governance information is transmitted among
all governance participants, so the governance information is the token of the Petri-net. Governance information can be the location of the muck truck, the behaviors of muck truck transportation, etc.

(2) [Circle]: Place. The round symbol represents the place where the resources are generated and stored (Petri & Reisig, 2008). The entities of muck waste management are the producers of governance information resources, so entities of muck waste management are the Petri-net’s place, such as government, muck transportation and disposal enterprises, construction units, etc.

(3) [Filled Circle]: Transition. A transition is an event that changes the state of the resource (Petri & Reisig, 2008). Governance activities can change the information produced by governance participants, so the governance activities are the transition of Petri-net.

(4) [Circle]: The combination of the place and the token. Combined with the definition of the previous token and place, this element means that the participant is undergoing muck waste governance.

(5) [Arrow]: Arrow. Arrows indicate the direction of flow and connect the place and transition (Petri & Reisig, 2008).

(6) Time delay: The duration of governance activities.

4.2. Process analysis of the traditional governance mode

The primary processes involved in solid waste management are: collection, transportation, and disposal or processing (Shrivastava et al., 2015). The following process describes the traditional governance mode.

(1) Muck waste collection: The construction site is the source of muck waste, so the construction unit needs to deal with the transportation and disposal of muck waste related certificates. After that, construction units should collect muck waste according to classification standards and preprocess muck waste if necessary.

(2) Muck waste transportation: Muck waste will be transported by an approved enterprise engaged in muck waste transportation services. Under the traditional governance mode, the public sector sends supervisors to inspect and spot check the transportation situation of muck waste and use traditional tools such as recorders and paper and pen to record the inspection results.

(3) Muck waste disposal: The traditional way of disposing of muck waste is to transport it to landfills.

Table 1 and Fig. 3. depict the detailed regulatory events and time delay of muck waste management under the traditional governance mode.
<table>
<thead>
<tr>
<th>Place</th>
<th>Meaning</th>
<th>Transition</th>
<th>Meaning</th>
<th>Time delay/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Construction unit</td>
<td>T1</td>
<td>Produce muck waste</td>
<td>0</td>
</tr>
<tr>
<td>P2</td>
<td>Construction unit</td>
<td>T2</td>
<td>Apply for relevant certificates</td>
<td>$t_1$</td>
</tr>
<tr>
<td>P3</td>
<td>Muck transportation and disposal enterprises</td>
<td>T3</td>
<td>Transport muck waste</td>
<td>0</td>
</tr>
<tr>
<td>P4</td>
<td>Public sector</td>
<td>T4</td>
<td>Intercept transportation situation of muck trucks, if qualified, record inspection results</td>
<td>$t_2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T5</td>
<td>If the transportation situation of muck truck is illegal, the public sector will give a punishment</td>
<td>$t_3$</td>
</tr>
<tr>
<td>P5</td>
<td>Illegal muck transportation and disposal enterprises</td>
<td>T6</td>
<td>Accept the punishment and apply for relevant certificates again</td>
<td>$t_4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T7</td>
<td>If the enterprises refuse to accept the punishment, they will be handed over to the court for compulsory execution</td>
<td>$t_5$</td>
</tr>
<tr>
<td>P6</td>
<td>Law enforcement department</td>
<td>T8</td>
<td>Mete out heavier punishment</td>
<td>$t_6$</td>
</tr>
<tr>
<td>P7</td>
<td>Public sector</td>
<td>T9</td>
<td>Record the results</td>
<td>0</td>
</tr>
<tr>
<td>P8</td>
<td>Muck transportation and disposal enterprises</td>
<td>T10</td>
<td>Transport muck waste to landfills</td>
<td>0</td>
</tr>
<tr>
<td>P9</td>
<td>Landfills</td>
<td>T11</td>
<td>Virtual transition</td>
<td>0</td>
</tr>
</tbody>
</table>

### 4.3. Process analysis of the platform governance mode

Muck waste management under the platform governance mode denotes the platform participates in muck waste supervision as a third-party. The platform can automatically collect data on violations of muck waste management through technical means. The acquisition of the muck waste stream data has been transferred from offline to online, which improves the efficiency of the monitoring of muck trucks.

Under the platform governance mode, the muck truck needs to be loaded with intelligent terminal equipment, such as intelligent cameras, and interactive display screens. The equipment will collect data in real time and be uploaded to the platform. If muck trucks have violations, the system will automatically report the alarm information to the platform, and the platform will generate control instructions to the vehicle terminals, such as limiting the speed of the muck truck or locking the truck. The platform will
review all kinds of violations and assign them to the corresponding law enforcement departments. The public sector can trace illegal vehicles and drivers according to the data or video evidence reported by the platform and notify the illegal muck transportation and disposal enterprises to make a rectification. After the rectification of illegal enterprises and reply to relevant departments, the platform will input the rectification results into the system for record. For the recycling part of the CE, the platform will release the information of muck waste that can be used as material for other construction projects or construction waste resource utilization enterprises. Table 2 and Fig. 4. depict the detailed regulatory events and time delay of muck waste management under the platform governance mode.

### Table 2
**Places, transitions and time delay under the platform governance mode**

<table>
<thead>
<tr>
<th>Place</th>
<th>Meaning</th>
<th>Transition</th>
<th>Meaning</th>
<th>Time delay/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Construction unit</td>
<td>T1</td>
<td>Production of muck</td>
<td>0</td>
</tr>
<tr>
<td>P2</td>
<td>Construction unit</td>
<td>T2</td>
<td>Apply for relevant certificates and register muck waste information</td>
<td>t₁</td>
</tr>
<tr>
<td>P3</td>
<td>Muck waste management platform</td>
<td>T3</td>
<td>Send the relevant certificates and release the information of muck waste</td>
<td>0</td>
</tr>
<tr>
<td>P4</td>
<td>Muck transportation and disposal enterprises</td>
<td>T4</td>
<td>Transport muck waste</td>
<td>0</td>
</tr>
<tr>
<td>P5</td>
<td>Muck truck intelligent supervision platform</td>
<td>T5</td>
<td>Collect muck waste stream data in time, and compare with the standard. If qualified, record the results</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>T6</td>
<td>If the data is not up to standard, the platform will generate control instructions and send violation information</td>
<td>0</td>
</tr>
<tr>
<td>P6</td>
<td>Public sector</td>
<td>T7</td>
<td>Accept violation information and give punishment</td>
<td>t₂</td>
</tr>
<tr>
<td>P7</td>
<td>Illegal enterprises</td>
<td>T8</td>
<td>Accept punishment and correcting violations</td>
<td>t₃</td>
</tr>
<tr>
<td>P8</td>
<td>Muck waste management platform</td>
<td>T9</td>
<td>Record the results</td>
<td>0</td>
</tr>
<tr>
<td>P9</td>
<td>Muck transportation and disposal enterprises</td>
<td>T10</td>
<td>Transport muck waste to assigned location</td>
<td>0</td>
</tr>
<tr>
<td>P10</td>
<td>Assigned location</td>
<td>T11</td>
<td>Virtual transition</td>
<td>0</td>
</tr>
</tbody>
</table>
4.4 Comparative evaluation of the process of the two governance modes

Under the traditional governance mode, an imbalance between muck waste production and ability to manage it is one of the biggest challenges and problems faced by public sector managers in handling muck waste (Abdul & Syafrudin, 2018). There is an information asymmetry between the public sector and regulated enterprises. The efficiency of regulation generally depends on the quantity and quality of information; the public sector is the information inferior side, while the enterprises are the information superior side (Zhao et al., 2007). Due to the limitation of labor, material and financial resources, the supervisory behavior of the public sector is limited. It is impossible for managers to monitor the disposal of waste in real time, and oversight will inevitably occur. Under the circumstance of information asymmetry, the condition for regulated enterprises to comply with the public sector is the punishment cost and incentive measure (Shen and Wang, 2018). The muck transportation and disposal industry has a large profit margin, and the punishment cost is far lower than the income, so the punishment cost is not sufficient as a deterrent for enterprises.

By contrast, the muck waste management platform can increase cooperation with the public sector and improve the performance of management under the traditional governance mode. Figure 4. show that the platform helps to reduce information asymmetry between the public sector and regulated enterprises via the ability to integrate information resources. The platform can obtain governance information in real time through on-board terminal equipment, and timely alarm for the violations of muck waste transportation and disposal. The platform also has the function of governance and information storage. Through the data statistics and analysis functions of the platform, the platform can assist government supervisors to make more effective decisions.

5. Case Study

5.1. Case description

Since 2020, Nanjing’s muck smart supervision platform has become a powerful assistant for various muck waste management activities and clearance. The main role of the platform is to provide cross-regional and cross-departmental efficient supervision services centering on government supervision, and improve the intelligent level of supervision. Through real-time collection of activity data of muck waste in Nanjing, the platform realizes the whole process of data traceability and non-tampering, and establishes a credit system for the whole industry chain. After the platform was put into operation, the processing time for certificates was reduced from an average of 2–3 days to a few hours, greatly improving efficiency.

5.2. Evaluation of muck waste management process
Information on the time delay of critical muck waste management processes was obtained through a survey at Nanjing Jingzhu Wisdom Technology Company. By using Visual Object Net++ (A Petri-net simulation software) to build timed Petri-net models, the simulation results of muck waste management processes are indicated in Table 3 and Table 4. According to the results, the running time of the governance process under the platform governance mode is significantly shorter than that under the traditional governance mode. Therefore, the platform governance mode could be considered very useful for implementing the integrated and effective management of construction muck waste.

Table 3
Construction muck waste management process simulation results under the traditional governance mode

<table>
<thead>
<tr>
<th>Number</th>
<th>Process samples</th>
<th>Total process cycle time/ day</th>
<th>Average process cycle time/ day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>147</td>
<td>14.7</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>295</td>
<td>14.75</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>762</td>
<td>15.24</td>
</tr>
</tbody>
</table>

Table 4
Construction muck waste management process simulation results under the platform governance mode

<table>
<thead>
<tr>
<th>Number</th>
<th>Process samples</th>
<th>Total process cycle time/ day</th>
<th>Average process cycle time/ day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>65</td>
<td>6.5</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>134</td>
<td>6.7</td>
</tr>
<tr>
<td>3</td>
<td>50</td>
<td>338</td>
<td>6.76</td>
</tr>
</tbody>
</table>

5.3. Benefits of muck waste management under the platform governance mode

5.3.1. Environmental benefits

Taking Nanjing’s muck smart supervision platform as an example of the muck waste management platform, this study verifies the actual benefit of the platform governance mode. After the generation and collection of muck waste from the construction site, the platform will track the muck waste stream from the source to the final disposal or reuse. This integrated platform can provide services, including preventing illegal dumping, scheduling muck to sites where it is needed, and classifying of muck waste. Finally, muck waste can be reused as concrete aggregate, industrial raw material and growing medium to reduce carbon emissions. To date, Nanjing’s demolition and construction waste resource utilization rate has exceeded 90%. Nearly 3 million tons of construction waste have been recycled, saving approximately 1.8 million cubic meters of landfill space resources and saving nearly 100 million yuan in transportation
and landfill costs. Accordingly, problems of environmental pollution and land encroachment have also been improved.

### 5.3.2. Economic benefits

Platforms can reduce transaction costs that are the sum of bargaining, information, and enforcement costs (Nurvala, 2015). Under the platform governance mode, the platform can integrate modern information technology and governance systems of the public sector to adequately supervise muck waste management activities and provide means of collaboration between participants. The core of platform governance model value co-creation lies in data sharing between different participants. In this sense, the governance mode will be transformed from extensive management to delicacy management, which can reduce time waste, cost waste, and labor waste and provide more open and sustainable government services. By using the information data provided by the platform, residue transportation and disposal enterprises can also achieve the vision of reducing costs and increasing performance according to regulatory requirements and their own production management needs in the future.

### 6. Conclusion

The inefficient management of muck waste has resulted in significant quantities of waste disposed in landfills or even illegally dumped without environmental protection measures. If an increasing amount of muck waste is disposed of improperly, it will seriously affect the sustainable development of the social economy and ecological environment. Therefore, this paper explored the feasibility of providing the platform governance mode for muck waste as an integrated and effective management mode for current practices of muck waste management and resource recovery in China, which is also the main theoretical contribution of this study. After researching the characteristics of the platform governance mode for muck waste management and applying Petri-net theory and a case study to process analysis, we find that platform governance mode can significantly improve the efficiency of the management of muck waste, which will provide economic and environmental benefits. The platform governance mode in a circular economy is a comprehensive solution to the current muck waste accumulation problem and should be encouraged by the government.

To improve the efficiency of the muck waste management processes, it is proposed to create a specialized platform that performs specific functions of coordinating material and information resources, which will track and coordinate the entire life cycle of waste from the source to the place of disposal or recycling. There must be fruitful cooperation between the public sector waste management authorities and related enterprises to eliminate the phenomenon of information asymmetry and to establish an efficient and integrated management system for muck waste. One of the key limitations to this study was the lack of analysis of waste reduction from the source. Reducing the source of construction waste is a key step to control waste generation (Liu et al., 2020) and building information modeling (BIM) can significantly reduce the amount of waste in construction (Kang et al., 2022). In future research, consideration should be given to the combination of platform governance mode and BIM to avoid the irrational generation of waste.
Declarations

Ethics approval
Not applicable

Consent to participate
Not applicable

Consent for publish
Not applicable

Availability of data and materials
The data and materials used during the current study are available from the corresponding author upon reasonable request.

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Authors’ contributions
Weiwei Wu: conceptualization, methodology, data collection, results analysis, writing and editing; Youying Yin: methodology, data collection, results analysis, writing and editing; Jian Li Hao: conceptualization, supervision, review and editing; Wenting Ma: data collection, review and editing; Guobin Gong: supervision, review and editing; Shiwang Yu: data collection, review and editing. All the authors contributed to the paper and approved the final version.

References


Figures
Figure 1

Two-sided market structure of muck waste management platform
Figure 2

Platform governance mode framework for muck waste management

Figure 3
Figure 4

Petri-net model of muck waste management process under the platform governance mode