Article

Governing the Moral Hazard in China’s Sponge City Projects: A Managerial Analysis of the Construction in the Non-Public Land

Tianyu Ma, Zhuofu Wang and Jiyong Ding *

Department of Engineering Management and Economy, Institute of Engineering Management, Business School, Hohai University, Nanjing 211100, China; maty@hhu.edu.cn (T.M.); zfwang@hhu.edu.cn (Z.W.)
* Correspondence: jyding@hhu.edu.cn; Tel.: +86-25-6851-4710

Received: 12 July 2018; Accepted: 22 August 2018; Published: 24 August 2018

Abstract: As a new development mode for solving urban water control problems, a sponge city has been widely concerned and steadily promoted in China. The source engineering in the non-public land is called a low-impact development system. Although it is an important part of a sponge city, the effect of its construction and operation is not ideal at present. The main reason for this lies in the moral hazard behavior of the developer who is the responsible party and the agent. In this research, governance mechanisms for preventing the moral hazard behavior are put forward. Additionally, corresponding models are constructed and designed based on incentive theory and project governance theory. Furthermore, the existence constraint conditions of different governance mechanisms are obtained, as well as the optimal reward and punishment of the government. Meanwhile, this paper calculated the expected returns of the government and the developer. The result shows that project completion probability and supervision cost are two key factors affecting the choice of the governance mechanisms. According to different value of project completion probability and supervision cost, this paper evaluated the selection conditions of different governance mechanisms. Moreover, this research puts forward some governing tactics and suggestions for preventing the developer’s moral hazard behavior, in order to improve the effect of project construction, and promote sponge cities to develop in a more efficient and sustainable manner.

Keywords: sponge city; low-impact development (LID) system; non-public land; moral hazard; governance mechanism

1. Introduction

With the rapid development of urbanization, the ecological environment is sacrificed and impervious surfaces increase, which results in a decrease of water storage capacity of urban ecological systems and greatly influences water quality [1]. Additionally, the groundwater overexploitation in northern cities and the severe waterlogging in southern cities have become very urgent problems of urban development in China. In 2014, the Chinese government proposed to construct Sponge Cities to solve water control problems. As a new sustainable development pattern [2,3], the sponge city has been widely concerned, and been steadily promoted, on the national policy level [4,5]. However, the completed projects do not meet the expected goals. Although some of the projects have achieved initial success, the overall effect is not desirable. Furthermore, many cities still suffer from severe waterlogging disasters [6,7]. The main reason lies in the overreliance on technologies and the negligence of management. This paper deems it necessary to make it clear that the construction of the sponge city needs not only technical support, but also an effective governance mechanism [8]. Only bringing into play the advantage of consolidation in the technologies and management can ensure the sustainable development of a sponge city [9].
Originally, Australia’s scholars used “sponge” to describe the adsorption effect of cities on the surrounding rural population [10,11], and then researchers used the physical characteristics of the sponge for urban water treatment. Henceforth, the concept of a sponge city was born. A sponge city is described as follows: “urban areas can be like a sponge, with good resilience in adapting to environmental changes and dealing with natural disasters; and can absorb water, store water, permeate water and purify water during the rain, then release and use the stored water” [12]. A sponge city is considered to be an ecological and innovative route for achieving urban rainstorm detention and water storage function [13]. It can be divided into three construction systems, namely, a low-impact development (LID) system as the source engineering [12], urban pipe duct drainage system (UPDDS) as the middle engineering, and excessive rainfall runoff discharge system (ERRDS) as the terminal engineering. Among them, the LID system is a completely new concept to many countries. However, a sponge city precisely emphasizes the source control function by the LID system, and brings the LID system into focus.

The LID system can eliminate the negative impact caused by the increasing urbanization [14], and make the hydrologic state return to its original state through micro-scale decentralized control measures [15] so as to realize water ecological balance [16]. It includes structural practice and non-structural dimensions [17], and China concentrates more on structural practice, including pervious pavement, green roofs, vegetation filter belts and so on, as shown in Table 1 [3,12].

Table 1. Typical LID facilities and their functions.

<table>
<thead>
<tr>
<th>Facilities</th>
<th>Permeation</th>
<th>Retention</th>
<th>Storage</th>
<th>Purification</th>
<th>Use</th>
<th>Drainage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pervious pavement</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rainwater collection</td>
<td></td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm water wetlands</td>
<td></td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permeable pavement</td>
<td>√</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green roofs</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sunken greenbelt</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation filter belts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bio retention</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The “√” means that the facility includes the corresponding function.

Although the LID system is known under different names, its practice contents are the same in different countries. For example, water-sensitive urban design (WSUD) in Australia, sustainable drainage systems (SUDS) in the United Kingdom, low-impact urban design and development (LIUDD) in New Zealand, best management practices (BMPs) and low-impact development (LID) in the United States [18,19], and so on. In contrast to the developed countries, research work focusing on urban sustainable development started late in China. However, China has sufficient technical experience in treating water problems. Indeed, as early as twenty years ago, China had successfully applied the ecological filter bed function of high permeability concrete to river bank treatment works [20].

LID systems are implemented on two kinds of lands: public lands and non-public lands. Significantly, the non-public lands with a clear developer accounts for about 75% of the total lands on which sponge cities are built [21]. As for the construction of a sponge city on non-public land part, the Chinese government department (hereinafter referred to as the government) incorporates construction requirements and related parameters into the land leasing contract, and the developer is responsible for the construction and implementation. Thus, a principal-agent relationship is formed between the developer and the government. Undoubtedly, the goal of the government (principal) is not consistent with the developers’ (agent). Specifically, the government aims to achieve the construction goals of the sponge city for urban sustainable development while the developer pursues maximize profits and commonly lacks of social responsibility. Therefore, as the responsible body and the agent
of sponge city construction, the developer tends to engage in some moral hazard behavior, such as cheating in work and cutting down on materials.

Moral hazard is very common in contracts and may occur under information asymmetry, incomplete risk consequences, and lack of supervision [22]. It can be defined as “People who engage in economic activities making maximum efforts to improve their own effectiveness while someone else [is] bearing the cost if things go badly” [23,24]. For instance, in the principal–agent problem, the agent with more information may take hidden action or inaction when the principal cannot completely monitor, which leads to the loss of the principal and/or the profit of the agent. Moral hazard reduces the efficiency and stability of an organization [25], so it is necessary to take measures to prevent and control it, such as incentive mechanisms, contract arrangements, corporate cultural development [26,27], and so on. This research focused on the moral hazard behavior by the developer during the construction of a LID system in non-public lands, since there is little discussion on such managerial analysis in the literature of the sponge city projects.

The appearance of moral hazard is mainly due to two reasons. On the one hand, building a LID system not only increases the construction cost, but also has little effect on the land development, so the developer lacks the motivation to construct the LID system meticulously. Moreover, in order to pursue its own economic interests, the developer will behave opposing the contract requirements, such as engage in crude construction and lower the construction standards. On the other hand, the supervision over the sponge city projects’ process has not yet been carried out by the government, and there are no concrete means to assess the construction indices, which give the developer the space to escape from its construction responsibility. Thus, the land contracts between the government and the developer is quite incomplete [28,29]. Additionally, the stronger the contract incompleteness is, the greater the moral hazard the government will face.

However, there is little research on the managerial and economic problems of sponge city projects, with least of the specific research being on the outstanding moral hazard problems with respect to non-public land. Fewer scholars have put forward some countermeasures and suggestions aimed at solving the managerial and economic problems in the sponge city projects. Li et al. [9] proposed that the lack of a managerial mechanism has become an urgent problem in the sustainable development of the sponge city, and they put forward a guarantee mechanism consisting of an organization guarantee, a system guarantee, a technology guarantee, a fund guarantee, and public participation. Xiao [30] carries out an economic analysis on the sponge city projects from two perspectives of the government and the project manager, and states that the sustainable management and operation of the sponge city projects remain questionable. Li et al. [5] introduced an idea of “management with intelligence”, and analyzed the performance evaluation of sponge city projects through three stages of planning, construction, and operation management. Yu et al. believe that the construction of a sponge city not only depends on superior engineering technology [31,32], but also systematic planning and management [33,34], in order to achieve the goal of “natural accumulation, natural infiltration and natural purification” [35]. Furthermore, the above results provide a theoretical reference of effective organization and management in the construction of a sponge city.

In other fields, moral hazard has been quite well discussed, from which we can also draw lessons. The original research of moral hazard was to study the opportunistic behavior in the insurance contract [36]. Subsequently, Arnott et al. applied it into contract theory, and designed the transaction contract under moral hazard situation [37]. From the perspective of incentive and asymmetric information, Inés et al. developed the moral hazard model and proposed an optimal contract under different effort level [38]. These extant research achievements on moral hazard have provided a powerful reference for this paper.

The main objective of this research is to design a mechanism to govern the developer’s moral hazard behavior, and to draw out specific strategies and suggestions, so as to fill the existing research gaps. The LID system in the non-public land not only bears the function of reducing runoff, protecting ecology, and utilizing rainwater, but also connects with the UPDDS and the ERRDS which,
furthermore, directly affects the operation effect of the two follow-up systems. According to the relevant research and successful experience, this paper strives to design a management frame for the sustainable development of sponge city projects in the future.

2. Materials and Methods

2.1. Research Boundary and Model Assumptions

At present, a precondition-method is mostly used to allocate the construction indices in the construction of LID system, i.e., the government incorporates the construction indexes into the land transfer/lease contract, while the land developer organizes the project construction. Figure 1 shows the project governance structure of LID construction project in the non-public land. It demonstrates the relationship between participants in the project, and is in two layers with different governance subjects. In governance layer 1, government is the governance subject and governs the developer; while the developer is governance subject in layer 2, and governs supplier, contractor, and designer. Although the government has a regulatory relationship with participants in governance layer 2, this study is restricted to the governance layer 1, and aims at constructing the mechanism and strategy to govern the moral hazard behavior of the developer. Under this mode, a principal-agent relationship has been established between the government and the developer. Similar to [39], the government has two key roles in the principal-agent relationship as regulator and supervisor. As the regulator, the government is critical to set the objectives of the sponge city projects, and as the supervisor, it is also essential to control the obligations and responsibilities of the developer. Whereas, the aspects of supervisory measures and objectives control are addressed only to a limited extent.

![Figure 1. Project governance structure of the LID construction project.](image)

Incentive theory provides effective means to control individual behavior and guide project objectives [40]. Furthermore, the project governance theory has emerged in recent years. It draws from the incentive theory and the mainstream governance theory, and redefines the boundary of the construction project research [41]. The governance of the moral hazard in the LID system belongs to these categories, which is to standardize, coordinate, control, and guide the sustainable activities of the developer, on the basis of distributing the rights, responsibilities, and benefits between the government and the developer.

According to the incentive theory and the project governance theory, there are two basic mechanisms to prevent moral hazard. One is the reward and punishment mechanism (RPM), and the
other is the supervision mechanism (SpM) [42–44]. In general, these governance mechanisms aims to provide scientific and reasonable measures to improve the efforts level of the developer, on the premise of meeting the participation constraint and the incentive compatible constraint. It can greatly help to achieve the optimization effect of the LID system in the non-public land. Of course, the success of any theoretical research paradigm is inseparable from its abstractions and hypotheses [45], so the following assumptions are proposed to delimit the boundary of this research problem.

**Hypothesis 1 (H1).** The developer is only responsible for the indicators given in the contract, but not responsible for the overall planning index of the SPONGE CITY projects. It is because that only the LID system in the non-public land is to be constructed by the developer, which is just a part of the sponge city projects.

**Hypothesis 2 (H2).** The government (principal) is risk neutral, while the developer (agent) is risk averse.

**Hypothesis 3 (H3).** The developer has two kinds of behavior space: work hard and be lazy, and the non-execution situation does not exist. If working hard, the developer can complete the construction index, and may do better. If being lazy, the developer can also achieve the construction index with a completion probability p. That means, even if working negligent and lazily, the developer also has a successful probability and just not doing it better.

**Hypothesis 4 (H4).** Let the effort level of the developer be e. When e > 0, the developer pays an extra cost which is denoted as C(e), and when e ≤ 0, the developer does not pay any extra cost.

**Hypothesis 5 (H5).** The supervision level of the government is e0. When e0 > 0, the government pays an regulatory cost, denoted as C(e0), when e0 = 0, the government does not pay any cost. Additionally, the government will be able to distinguish at varying degrees whether the developer is lazy, as long as paying the regulatory cost.

2.2. The Existent Conditions and Selective Conditions of the Governance Mechanism

As mentioned in Section 2.1, there are two basic governance mechanisms, the reward and punishment mechanism (RPM) and the supervision mechanism (SpM). Under RPM, the rewards and punishments gotten by the developer will be linked to the completion effect of the LID system. When the completion effect is better than the agreement in the contracts, the government will reward the developer, otherwise punish it. It can be seen that the RPM pays more attention to the evaluation of the final results, and does not directly observe and verify the agent’s process behavior. Thus, the core problem of RPM is how to set the incentive intensity to achieve the balance between incentives cost and incentive effect.

On the contrary, under the SpM, the government will supervise the developer’s process behavior, and links the supervisory results with the intensity of rewards and punishments. According to the randomness of supervisory behavior, the SpM can be divided into two types: random supervision mechanism (R-SpM) and deterministic supervision mechanism (D-SpM). Under the D-SpM, the developer clarifies the government’s supervisory behavior, including the time node and the supervisory content. The D-SpM was introduced early in principal-agent model [46], and solved many managerial problems. However, its supervisory cost is too high, while the R-SpM can effectively reduce the supervisory cost [47]. Under the R-SpM, the government’s supervisory behavior is not clearly known by the developer, and the government supervises the developer with a certain probability while the developer also has a probability of effort. This dynamic mode may have a deterrent effect, which makes the developer consciously works hard to achieve the optimal incentive [48].

Table 2 shows three strategic combinations between the government and the developer. Because of implementing the governance mechanism, the strategic combination (Not-Supervise, Lazy) will not actually happen, so it is invalid. Additionally, the strategic combination (Supervise, Hardworking)
has two types: R-SpM and D-SpM. The above mechanisms have their own existent and selective conditions, and are different in the governance costs. Therefore, it is necessary to build a corresponding model for comparing their effectiveness.

Table 2. Governance mechanisms under different behaviors of government and developer

<table>
<thead>
<tr>
<th>Government</th>
<th>Developer</th>
<th>Hardworking</th>
<th>Lazy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervise</td>
<td>Deterministic/random supervision mechanism</td>
<td>Non-cooperative punishment mechanism</td>
<td></td>
</tr>
<tr>
<td>Not-Supervise</td>
<td>Cooperative reward mechanism</td>
<td>Non-existent</td>
<td></td>
</tr>
</tbody>
</table>

2.2.1. Cooperative Reward and Non-Cooperative Punishment Mechanism

Under the cooperative reward mechanism, the government will reward the developer with \( t(w) \) as long as the LID system construction index meets/exceeds the agreement. The \( w \) indicates the completed level that is superior to the agreed index; and when \( w = 1 \), it means the completed level just coincides with stipulation. In this situation, the developer can gain an expected return as \( t(w) - C(e) \); While, if being lazy, the developer can also achieve the construction index with a completion probability \( p \), so the expected return is \( pt(w) \). Thus, we can obtain:

Constraint 1: \( t(w) - C(e) > 0 \), \( pt(w) > 0 \), \( w \geq 1 \)

Although the work effect of the developer does not bring benefits to the government, it will reduce the loss of public welfare caused by project failure. It can define that the invisible profit obtained by the government is \( T(w) \). Accordingly, when the developer is working hard, the expected return of the government is \( T(w) - t(w) \); and while the developer is lazy, it is \( pt(w) \). At the same time, the incentive scheme designed by the government should satisfy incentive compatibility and participation constraint. Thus:

Constraint 2: \( T(w) - t(w) \geq pT(w) > 0 \);
Constraint 3: \( t(w) - C(e) \geq pt(w) > 0 \).

To satisfy the above constraints, following model can be established. Hereby, the government needs to find an optimal \( T(w) \).

\[
\begin{align*}
\text{Max}(T(w) - t(w)) \\
\text{St.} \left\{ \begin{array}{l}
T(w) - t(w) \geq pT(w) > 0 \\
t(w) - C(e) \geq pt(w) > 0
\end{array} \right.
\end{align*}
\]

(1)

From Equation (1), it can be derived that:

\[
t(w) = \frac{C(e)}{1 - p}, p \leq 1 - \sqrt{\frac{C(e)}{T(w)}}.
\]

Here, the maximum expected return of the government can be given by:

\[
ER_1 = T(w) - \frac{C(e)}{1 - p}.
\]

Additionally, the expected return of the developer is:

\[
ER_2 = \frac{C(e)}{1 - p} - C(e).
\]

The detailed deduction process of the equations is shown in Supplementary Material (1).
On the contrary, under the non-cooperative punishment mechanism, the government will punish the developer if their agreement fails to complete. The government can not only punish the developer economically, but can also carry out administrative penalties, such as disqualification. This research defines the government penalty is \( y(v) \), and the \( v \) represents the punishment level by the government; when the developer works hard, \( y(v) = 0 \). In addition, when the developer is lazy, it can save construction costs as \( c(d) \), and \( d \) indicates the unfinished degree of the project. At this point, the project completion probability is \( p \), so the \( ER_2 \) is \( c(d) - py(v) \); while the government’s loss caused by project failure is \( L(d) \), and the \( ER_1 \) is \( p[y(v) - L(d)] \). If the government wants to motivate the developer to work hard, it must ensure that the \( ER_1 \) is positive and the \( ER_2 \) is negative, i.e., \( c(d) - p y(v) \leq 0; p[y(v) - L(d)] \geq 0 \). Accordingly:

\[
y(v) \geq \frac{c(d)}{p}, y(v) \geq L(d).
\]

Therefore, the government with the dual identity of principal and executive can punish the developer, and the greater the penalty \( y(v) \) is, the more effective the non-cooperative punishment mechanism will be, although the excessive punishment is unfair.

**Conclusion 1:** Only if the developer is lazy, but can still complete the LID construction with a probability \( p \leq 1 - \sqrt{\frac{C(v)}{T(w)}} \), the rewards and punishments mechanism can be implemented. In this case, the probability that the developer is rewarded for laziness is very low, but the penalty for laziness is very large, so the developer’s lazy space is effectively reduced. The government can give enough incentives to the developer, while the government can also prevent the developer from laziness by imposing sufficient punishment. As a power center, the government can take excessive punishment, and the punishment mechanism will be more effective when the \( y(v) \) is greater. Though increasing \( y(v) \) is efficient, it is obviously unfair. Accordingly, the punishment mechanism is more suitable for the auxiliary and supplement of other mechanisms.

### 2.2.2. Deterministic Supervision Mechanism (D-SpM)

Under the deterministic supervision mechanism, the government will supervise the developer’s process behavior, and pay a monitoring cost as \( c(e_0) \). Once the lazy behavior is found, the developer will be punished by the government, such as rework and fines, and the punishment is \( y(v) \). In addition, if the developer works hard, the government will pay the reward \( t(w) \) to the developer. Here, the expected return of the government and developer is shown in Table 3.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>( ER )</th>
<th>( ER_1 )</th>
<th>( ER_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lazy</td>
<td>( y(v) - c(e_0) )</td>
<td>( c(d) - y(v) )</td>
<td>( t(w) - t(w) - c(e_0) )</td>
</tr>
<tr>
<td>Hardworking</td>
<td>( T(w) - t(w) - c(e_0) )</td>
<td>( t(w) - C(v) )</td>
<td>( t(w) - C(e) )</td>
</tr>
</tbody>
</table>

Thus, only when \( t(w) - C(e) > 0 \) and \( c(d) - y(v) < 0 \), will the developer choose to work hard. Meanwhile, the purpose of the D-SpM is to reduce the cooperative rewards to the developers, so as to attain the developer’s effort with minimum incentive cost. Thus, only when the cost of implementing the D-SpM is less than the cooperative reward mechanism, the government will choose the D-SpM. We can establish the following Equation (2) accordingly:

\[
\begin{align*}
St., & \quad \text{Max}(T(w) - t(w) - c(e_0)) \\
& \begin{cases} 
\begin{align*}
& t(w) - C(e) > 0 \quad \text{if } c(d) - y(v) < 0 \\
& y(v) - c(e_0) \leq T(w) - t(w) - c(e_0) \\
& t(w) + c(e_0) < \frac{C(e)}{1-p}
\end{align*}
\end{cases}
\end{align*}
\]
According to $t(w) > C(e)$, we can set $t(w) = C(e) + \sigma$, where $\sigma$ represents a trace. Since the smaller $t(w)$ is better for the government, its theoretical value is $C(e)$, $\sigma = 0$.

Thus, it can be calculated that $ER_1 = T(w) - C(e) - c(e_0)$, and $ER_2 = \sigma$.

The detailed deduction process of the equations is shown in Supplementary Material (2).

**Conclusion 2:** Only when the punishment $y(v)$ is far greater than the cost-savings $c(d)$, can the government adopt the D-SpM. Under this mechanism, the government will punish the developer with high penalties for its laziness. In order to avoid the punishment, the developer is bound to work hard. Therefore, when the supervision cost $c(e_0)$ is not high and less than the total cost under the RPM, the government can implement the D-SpM. Otherwise, this mechanism will not be adopted.

### 2.2.3. Random Supervision Mechanism (R-SpM)

Unlike deterministic supervision, the government monitors the developer with a probability $\alpha$ under the R-SpM, while the developer does not know the government’s supervisory behavior. Although the R-SpM has a deterrent effect on the developer, it gives the developer a hitchhiking opportunity to work hard with a probability $\beta$. The developer can gain profits from laziness and obtain rewards for completing the project with the probability $p$. Thus, there are four behavior combinations between the government and the developer, and Table 4 shows different values of the expected return under different behavior combinations.

### Table 4. Expected return ($ER_1$, $ER_2$) under different behavior combinations.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Supervise with $\alpha$</th>
<th>Not-Supervise with $1 - \alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardworking</td>
<td>$T(w) - t(w) - c(e_0)$</td>
<td>$t(w) - C(e)$</td>
</tr>
<tr>
<td>Lazy</td>
<td>$y(v) - c(e_0)$</td>
<td>$c(d) - y(v)$</td>
</tr>
</tbody>
</table>

Accordingly, the final expected return of the two parties can be expressed as:

$ER_1 = a[\beta[T(w) - t(w) - c(e_0)] + (1 - \beta)[y(v) - c(e_0)] + (1 - a)]\beta[T(w) - t(w)] + (1 - \beta)[p(T(w) - t(w))]$

$ER_2 = a[\beta[t(w) - C(e)] + (1 - \beta)[c(d) - y(v)] + (1 - a)]\beta[t(w) - C(e)] + (1 - \beta)[c(d) + p t(w)]$

If the R-SpM is effective, the $ER_2$ for the hardworking developer should be greater than the lazy developer. Therefore, it needs to meet $t(w) - C(e) > c(d) - y(v)$ and $t(w) - C(e) > c(d) + p t(w)$. Moreover, in order to avoid the developer’s laziness, the $ER_1$ under the government supervises should be greater. Thus, the following constraints can be obtained:

**Constraint 1:** $C(e) + c(d) - y(v) < t(w)\frac{C(e) + c(d)}{1 - p}$

**Constraint 2:** $T(w) - t(w) - c(e_0) > p[T(w) - t(w)]$, i.e., $c(e_0) < (1 - p)\frac{t(w)}{T(w) - t(w)}$.

Accordingly, we can establish the following Equation (3):

$$\begin{align*}
\max (ER_1) & \text{s.t.} \\
\frac{\partial ER_1}{\partial \alpha} & = 0 \\
\frac{\partial ER_2}{\partial \alpha} & = 0 \\
ER_1 & \geq 0 \\
ER_2 & \geq 0 \\
t(w) & > \frac{C(e) + c(d)}{1 - p} \\
c(e_0) & < (1 - p)[T(w) - t(w)]
\end{align*}$$

By Equation (3), the optimal supervision probability of the government is $\alpha = \frac{c(d) + p t(w)}{p t(w) - y(v)}$, and the optimal effort probability of the developer is $\beta = \frac{p[T(w) + c(e_0) - p t(w) - y(v)]}{p t(w) - y(v)}$. Then, putting the $\alpha$ and $\beta$ into
Equation (3), together with $c(e_0) < (1 - p)\cdot[ T(w) - t(w) ]$ and $T(w) - t(w) - c(e_0) > y(v) - c(e_0)$, it can derive that $c(e_0) < T(w) - t(w)$.

Accordingly, a simplified Equation (4) can be obtained by substituting $\alpha$ and $\beta$ into Equation (3):

$$
\begin{align*}
\text{Max}( & \frac{p(T(w)-t(w))^2 + [(1-p)c(e_0) - y(v)] (T(w)-t(w))}{p(T(w)-t(w)) - y(v)} ) \\
\text{St.} & \\
C(e) + c(d) - (1 - p)t(w) & < 0 \\
c(e_0) - [T(w) - t(w)] & < 0 \\
[T(w) - t(w)] - C(e) & > 0
\end{align*}
$$

Equation (5) can be established:

$$
\begin{align*}
\frac{\partial L}{\partial t} & = 0 \\
\frac{\partial L}{\partial \lambda_1} & = C(e) + c(d) - (1 - p)t(w) \\
\frac{\partial L}{\partial \lambda_2} & = [c(e_0) - T(w) + t(w)] \\
\frac{\partial L}{\partial \lambda_3} & = [T(w) - t(w) - C(e)] \\
\lambda_1[C(e) + c(d) - (1 - p)t(w)] & = 0 \\
\lambda_2[c(e_0) - T(w) + t(w)] & = 0 \\
\lambda_3[T(w) - t(w) - C(e)] & = 0
\end{align*}
$$

Further, by solving Equation (5), it can be obtained the reward from the government ($t(w)$), the supervision probability of the government ($\alpha$), and the effort probability of the developer ($\beta$) under different ranges of the probability $p$ and the supervision cost $c(e_0)$ shown in Supplementary Material (3).

In fact, when $\alpha = 1$, the model goes back to the deterministic supervision mechanism; when $\alpha = 0$, the model returns to the reward and punishment mechanism. Therefore, excluding these two situations, the conditions for the establishment of the random supervision mechanism is:

$$
1 - \sqrt{\frac{C(e)}{T(w)}} \leq p \leq 1 - \frac{C(e)}{T(w)} \text{ along with } \frac{pC^2(e)}{T(w)(1 - p)} \leq c(e_0) \leq \frac{pC(e)}{1 - p}
$$

Or:

$$
p < 1 - \sqrt{\frac{C(e)}{T(w)}} \text{ along with } \frac{pC^2(e)}{T(w)(1 - p)} \leq c(e_0) \leq \frac{pC^2(e)}{T(w)(1 - p)^3}
$$

Thus, it can be calculated that the supervision probability is:

$$
\alpha = \frac{C(e)}{T(w)c(e_0)p(1 - p)} - \frac{1 - p}{p}
$$

The effort probability of the developer is:

$$
\beta = 1 - \sqrt{\frac{c(e_0)}{T(w)p(1 - p)}}
$$
The reward from the government is:

\[ t(w) = \frac{\sqrt{T(w)c(e_0)p(1-p)}}{p} \]

The maximum expected return of the government is:

\[ ER_1 = T(w) + \frac{c(e_0)(1-p)}{p} - \frac{2\sqrt{T(w)c(e_0)p(1-p)}}{p} \]

And, the expected return of the developer is:

\[ ER_2 = \frac{\sqrt{T(w)c(e_0)p(1-p)}}{p} - C(e) \]

**Conclusion 3:** The establishment of R-SpM requires the supervision cost \( c(e_0) \) and the completion probability \( p \) to meet certain conditions. As for a derivation of the function \( ER_1 \), it can be determined that \( ER_1 \) is a decreasing function of \( c(e_0) \), which indicates that the increase of supervision cost results in the increase of the government’s total cost. Additionally, the increase of \( e_0 \) is larger than the increase of \( w \), which represents that the increased amount of the efforts made by the developer is mainly due to the government’s supervision. While differentiating the function \( ER_2 \), it can be determined that \( ER_2 \) is an increasing function of \( c(e_0) \). The reason is that the increasing of the supervision cost will bring about the decrease of supervision probability \( \alpha \), which will reduce the threat of the random supervision to the developer. Hence, the government will gradually increase the reward in order to motivate the developer to work hard, until the mechanism changes into the cooperative reward mechanism. Consequently, the profit of the developer will increase.

3. Results and Discussion

3.1. Comparative Analysis of Optimal Mechanism

Through the above analysis, it is found that the implementation of reward, punishment, and supervision does not always promote the developer’s transformation from lazy to hardworking, and even it will bring the continuous accumulation of the government’s costs. In order to achieve the effectiveness of the governance mechanisms, it is necessary to design effective rewards and penalties to optimize the incentive effect. At the same time, according to the different value of \( p \), the government’s strategy and expected return will be different. After obtaining the existence conditions of each mechanism, it is necessary to further compare and analyze the optimal strategy under different probability \( p \), and the detailed calculation process of D-value of \( ER_1 \) under different mechanisms is shown in Supplementary Material (4).

(1) When \( 0 \leq p < 1 - \frac{C(e)}{T(w)} \), the R-SpM, the D-SpM and the cooperative reward mechanism are all conforms to the selection conditions. Thus, it needs to compare the \( ER_1 \) under different mechanisms combined with the value of \( c(e_0) \). Comparing the \( ER_1 \) under the R-SpM and the D-SpM, it can be found that the better choice for the government is the D-SpM.

Furthermore, comparing the \( ER_1 \) under the cooperative reward mechanism and the D-SpM, it is found that:

- When \( c(e_0) \geq \frac{pC(e)}{1-p} \), the better choice for the government is cooperative reward mechanism; and
- When \( c(e_0) \leq \frac{pC(e)}{1-p} \), the better choice for the government is D-SpM.

(2) when \( 1 - \frac{C(e)}{T(w)} \leq p \leq 1 - \frac{C(e)}{T(w)} \), the RPM is invalid, and the condition for the R-SpM’s establishment is \( \frac{pC(e)}{T(w)(1-p)} \leq c(e_0) \leq \frac{pC(e)}{1-p} \), and the condition for the D-SpM is \( c(e_0) \leq \frac{pC(e)}{1-p} \). Thus, when \( c(e_0) \leq \frac{pC(e)}{T(w)(1-p)} \), the better choice for the government is the D-SpM.
When $\frac{pC^2(e)}{T(w)(1-p)} \leq c(e_0) \leq \frac{pC(e)}{1-p}$, it needs to compare the $ER_1$ under the two mechanisms. According to the calculation in Supplementary Material (4), it must exist $c(e_0) = c$, making the $D$-value $= 0$. Thus, it can be obtained that,

When $\frac{pC^2(e)}{T(w)(1-p)} \leq c(e_0) \leq c$, the better choice for the government is the R-SpM; and

When $c \leq c(e_0) \leq \frac{pC(e)}{1-p}$, the better choice for the government is the D-SpM.

(3) When $1 - \frac{C(e)}{T(w)} \leq p \leq 1$, the mechanisms are all invalid, which shows that the projects are very easy to complete. It means that even if working extremely lazily, the developer is also most likely to complete the projects. However, a sponge city is not such an easy project. Thus, in this case, the incentive problem does no longer exist. Figure 2 shows the mechanisms’ selection in different cases.

![Diagram](image)

**Figure 2.** Selection of optimal mechanism in different situations.

By combining incentive methods with project governance, the above results are obtained. Incentive methods have not been extensively studied in engineering project governance in the past, but widely adopted in other fields such as outsourcing projects [44], business administration [49], and bank monitoring [48,50], etc. By virtue of the results, the method can obviously help solve the managerial problems encountered in engineering projects. Moreover, there is little research on the managerial and economic problems of sponge city projects, least of specific research on the outstanding moral hazard problems in non-public lands. This study has retained available parts of the method and removed non-existent situation. Additionally, this research added an invisible profit $T(w)$ of government in the method. Although this article has not changed the method too much, it has fully played the method’s positive role in this research.

### 3.2. Governing Tactics and Suggestions

The developer is the main responsibility body of the LID system construction in the non-public land. The developer’s behavior is crucial to the LID system and influences the sponge city. As mentioned, the contract’s incompleteness and the principal-agent relationship between the government and the developer are the source of the developer’s moral hazard behavior. In order to encourage the developer to work hard, the government should design a rational governance mechanism. Deriving from the above theoretical analysis, this research puts forward the following governance tactics and suggestions.

(1) The government should also incorporate the detailed planning contents of the LID system construction into the land transfer/lease contract, including detailed planning objectives, detailed evaluation indicators and specific implementation plans, etc. At present, the sponge city
construction only includes the final effect control index, which gives the developer a larger adjustment space. However, there exists much ambiguity and uncertainty in the detailed planning contents of the LID system. Thus, driven by interests, the developer will always choose the implementation plan which costs lower, but achieve the LID system construction goals difficultly. If the detailed planning contents are included in the contract, it can effectively limit the adjustable space of the developer, and ensure the implementation of the LID system from the source.

(2) The government should strengthen supervision over the developer and be more involved in the supervision and governance of the design and construction process through the LID system development, as well as strictly supervise the important implementation steps. Specifically:

a. In the examination and approval of the preliminary design, the government should review the LID technology, the vertical and plane layout, the project scale and its connection with the UPDDS, based on the detailed planning of the LID system determined by the land transfer/lease contract.

b. Only after analyzing the realization degree of the LID control targets and indicators, can the government give the developer an official.

c. In the supervision of the construction process, the government is necessary to take part in the acceptance of concealed engineering and the management of engineering change.

d. The government should carry out the acceptance and evaluation of the project in strict accordance with the design plan. Generally, the acceptance of a LID system construction project should be conducted after a rainy season operation inspection.

(3) According to the above arguments, the government should also incent the developer to work better. The government can establish a quality system for evaluating the LID system construction, which can divide the construction quality into three grades: unqualified, qualified, and excellent. On the basis of this index system, the government can be clearer to identify whether the developer is lazy, and determine a scheme of reward or punishment. Actually, several cities have proposed corresponding incentive policies, mainly including two kinds of reward methods mainly. One is that the government gives the developer money award directly from the financial contribution, or rewards the developer the land area. The reward amount per unit area is about 5% of the average cost per unit area of the LID system. The other is that the government pays operation and maintenance for the LID system within a certain period of time (such as 5–10 years).

4. Conclusions

Inadequate supervision and extensive construction are the critical reasons that hinder the sponge city to develop healthily and sustainably. In order to make up for the disregard of management, this research explored such a managerial and economic problem of moral hazard in the source engineering of the sponge city. This article established and calculated the governance mechanism models, the existence conditions of different mechanisms, the optimal reward and punishment amount, and the expected return of the government and the developer.

There are still many limits in this research, which are also the directions for further study. Firstly, there are limitations to the assumption of risk preference. This article assumes that the government is risk neutral and the developer is risk aversion, but there may be other combinations in practice. Especially, many of the previous studies have assumed that the government is risk neutral [41], but it can hardly believe that its practice is risk neutral as many public projects have been implemented hastily. The government even has shown opportunistic tendencies and rent-seeking behaviors. It explains that sometimes the government’s risk attitude is risk-seeking rather than neutral in order to obtain political achievements and benefits from engineering corruption. Secondly, this study only focuses on the construction stage of LID facilities on non-public lands. However, the developer is also responsible for the later stage of operation and maintenance. In this case, it is uncertain whether the developer will work hard at the construction stage to ensure the quality of operation and maintenance stage.
Lastly, this research focuses more on a theoretical analysis, and the future work should be aimed at the empirical evaluation of related parameters.

Rapid urbanization has promoted urban development and social progress, but it has also brought about the destruction of natural ecosystems. As a new concept and new mode of urban development, the sponge city can effectively alleviate the ecological and environmental problems caused by urbanization. It is an important transformation of urban construction from extensive development to delicacy management and ecological civilization, also more in consistent with the scientific argument that lucid waters and lush mountains are invaluable assets. In order to develop the sponge city sustainably, profound changes must be carried out in managerial ideas and methods, with a reasonable and effective governance mechanism being designed. Consequently, only by combining the positive effects of both technology and management, can it ensure the healthy and sustainable development of the sponge city.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/10/9/3018/s1, Table S1: Value of \( t(w) \), \( \alpha \) and \( \beta \) under different ranges of \( p \) and \( c(e_0) \).

Author Contributions: This manuscript is an achievement of the Doctoral research of T.M. under the supervision of Z.W. and J.D. T.M., and Z.W. designed the research, J.D. developed the structure, and T.M. wrote the paper. All the authors discussed the results and defined the aim of this research.

Funding: This research was supported by a grant from the Research on Innovation Path and Value-added Mechanism of Construction Project Transaction Mode (71402045) funded by the National Natural Science Foundation of China, and from the Risk Assessment Research on the Sponge City Construction (2017B18114) funded by Ministry of Education of China.

Acknowledgments: We are particularly grateful to the anonymous reviewers for their perceptive comments.

Conflicts of Interest: The authors declare no conflicts of interest.

References


27. Tulli, V.; Weinrich, G. Using Value-at-Risk to reconcile limited liability and the moral-hazard problem. *Decis. Econ. Financ.* 2015, 38, 93–118. [CrossRef]


38. Macho-Stadler, I.; Pérez-Castrillo, J.D. An Introduction to the Economics of Information: Incentives and Contracts; Shanghai University of Finance & Economics Press: Shanghai, China, 2004; pp. 27–32.
46. Radner, R. Monitoring Cooperative Agreements in a Repeated Principal-Agent Relationship. Econometrica 1981, 49, 1127–1148. [CrossRef]
49. Song, J. Futures market: Contractual arrangement to restrain moral hazard in teams. Econ. Theory 2012, 5, 163–189. [CrossRef]
50. Pagès, H. Bank monitoring incentives and optimal ABS. J. Financ. Intermed. 2013, 22, 30–54. [CrossRef]