Research on the application of PPP model in smart city projects

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Abstract. Compared with traditional infrastructure, where public-private partnerships (PPPs) have been widely used, smart city is a new field for PPP model application. Currently, the PPP model of smart city projects (SCPs) is faced with a tremendous number of problems. In view of this, according to the hierarchy and synergy characteristics of smart city construction, SCPs can be divided into three categories: the single structure, the cross structure, and the overall structure. This paper matches specific PPP operation models for different types of SCPs. Furthermore, the problem tree and target tree analysis methods are adopted to address the problem encountered in the profit-making model, and ultimately the “E-PPP” model is established as an effective solution. In addition, the proposed model can be used as an innovative one to release the constraints of infrastructure and public service supply in smart cities.

1. Introduction
Currently, the idea of the smart city is a research hot topic in urban development globally. The International Telecommunication Union considers smart city as an innovative solution that makes use of information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operation and competitiveness, while ensuring that it meets the needs of present and future generations with respect to social, economic and environmental aspects [1]. By implementing the “smart” solution, a large-scale investment and exceptional managerial skill – both of which often abound in private sectors but are insufficient in city governments – are required [2]. Therefore, the government has been launching a campaign to promote the PPP model to develop smart cities. In the context of China, the PPP model refers to the cooperation between the government and social capital, in which social capital includes private enterprises, profitable state-owned enterprises, and foreign-owned enterprises [3]. However, as the PPP model of the SCPs is still in its infancy in China, its application effect is not remarkable with few typical successful cases in practice. When the Ministry of Finance disposed of the PPP demonstration projects to verify the existing problems in 2018, 40% of smart city PPP projects were suspended because of the ambiguous operation models and the unclear profit-making model [4]. Consequently, research on the application of PPP model in SCPs is of great significance.

Domestic-related research has just started. At present, more exploration is at a practical level. Jiang et al. (2014) analyze the investment subject of SCPs [5]; Zhang et al. (2018) and Xu (2017) sort out the PPP model for local SCPs [6-7]; Li et al. (2018) and Zhou et al. (2017) conduct statistical analyses on the current situation of smart city PPP projects across China, and claim that the profit-making model is a key issue of smart city PPP projects [8-9]. In short, few studies have been able to draw on any structured research into the matching of PPP operation models and analyzing the profit-making model of SCPs. For this reason, this paper classifies SCPs and systematically explores the specific operation...
models and the profit-making model, and proposes the corresponding solution to enhance the effect of PPP model on smart city development.

2. Operation models of smart city PPP projects

From the perspective of suspending the demonstration projects, the PPP operation model of the SCPs is ambiguous. In order to facilitate the analysis of the operation model, it is necessary to classify SCPs appropriately first.

2.1. Classification of smart city projects

2.1.1. Hierarchy of smart city construction. As a top-down design, the smart city construction architecture is composed of top-level design, basic design, and application design. Figure 1 shows the specifics of each design.

![Figure 1. Schematic diagram of the smart city construction.](image)

In practice, according to the degree of urban informationization, the urban operation center can be constructed in the first place, and then superimposing various “smart” applications as needed. Or, based on urban needs and backgrounds, the “smart” applications of people’s livelihood can be developed as a priority, and then considering the connection of applications.

2.1.2. The synergy of smart city construction. “Smart” applications as are indicated in the above diagram are not isolated. A good example of a synergistic system is Amsterdam’s Smart Mobility solution. People can book parking lots in advance with an app which is linked to ambulances, traffic control and an electric grid that allows electric vehicle owners to store locally produced energy [10]. That’s to say, smart transportation can be packaged and operated in cooperation with smart health-care and smart grid to improve traffic as well as provide a positive chain reaction in other areas.

Based on the above analysis, this paper divides SCPs into three categories: the single structure, the cross structure, and the overall structure.

- Single structural projects have high professional requirements. Additionally, this structure involves two scenarios: level I single item and level II single item. For instance, Zhengzhou has built a smart community with smart old-age care, smart property and smart home [11]. The former is a level I single item, while last three are level II single items respectively. Any of this single structural project
functions independently.
- Cross structural projects, which consist of the single structure correlated to each other, are characterized by the difficulty in dividing the boundary of the projects.
- Overall structural projects involve the construction of three levels shown in Figure 1. This structure covers not only unrelated projects but also non-similar related projects.

2.2. Screening of PPP models of smart city projects
The primary problem to be addressed is who operates the SCPs. The operation of smart cities involves two core subjects: the government and the enterprise [12]. For the single structural project with simple business attribute and low complexity, if the government has its own professional operation organizations, and it could adopt service outsourcing. That is, the government takes responsibility for operation and maintenance, while the enterprise takes charge of the construction of non-core parts. Otherwise, it is more suitable for the enterprise to operate. Parts of projects in cross structure and overall structure might overlap with public management, and they could be rent back by the government after the construction of enterprises and the rest operated by enterprises. Moreover, smart city PPP projects involve new construction, renovation and existing projects [13], which could be divided based on the transfer of the asset access right, as shown in Table 1. Projects with different transferring processes could be operated by different subjects, which means operation models could be preliminary identified by two dimensions, including the transfer of asset access right and distribution of management right, as shown in the table below.

| Transfer of asset access right | Distribution of management right | Social capital to government | Government to social capital |
|-------------------------------|----------------------------------|-----------------------------|-----------------------------|
| Non-transfer (government ownership) | Social capital | BOT (BOOT/DBFOT) / BOO | TOT/ROT | Fully privatized |
| Social capital | DBO/O&M | Government to social capital to government | Government to social capital |
| Social capital to government | Government outsourcing | BOT | TOT/ROT | Fully privatized |

| Government to social capital/repurchase | Service outsourcing |
|--------------------------------------|---------------------|
| BLT | Government repurchase |

It is worth noting that the actual effect of Build-Own-Operate-Transfer (BOOT) and Design-Build-Finance-Operate-Transfer (DBFOT) have almost no difference compared with the Build-Operate-Transfer (BOT) [3], thus BOT model is used as the representative of them.

2.3. Matching of PPP models of smart city projects
The payment of PPP projects includes viability gap funding, user charges, and government payment [3]. To facilitate our description, the first two types are classified as user payment, and the latter is non-user payment.

The business attribute of the single structure is simple, especially the level II single item. Thus, the operation models can be selected directly based on whether the project is paid by users. The BOT or Build-Own-Operate (BOO) model could be adopted for user payment. As for non-user payment, adopting the BOT model is more attractive to social capital. Owing to the small scale of this project, the social capital could separately set up a special purpose vehicle (SPV), which is responsible for the investment, financing, construction and operation; or without setting up SPV, Design-Build-Operate (DBO) model is adopted and the government undertakes the full investment in construction.

The business attribute of the cross structure is diversity, as it involves the combined construction of projects, including the combination of new projects and the combination between new and old projects. The former could select the corresponding model according to whether the user pays. Or, the government could build part of the projects and transfer at a low price or free to attract social capital participation. Then, the social capital is responsible for building the rest and unified operation and maintenance, namely, government construction + transfer + BOT. The latter could adopt BOT + Renovate-Operate-Transfer (ROT) or BOT + Operation and Maintenance (O&M) combination models. At this time, SPV is responsible for the construction of major projects, while others could be built
through bidding or subcontracting.

The business attribute of the overall structure is complex, and its manageability is weak. The government could transfer part of the existing competitive projects to social capital in the form of Transfer-Operate-Transfer (TOT) + BOT/BOO. If some projects are highly confidential, they should be rent by government in the form of Build-Lease-Transfer (BLT) + BOT/BOO. Given that the huge size of sub-projects, this structural project could be divided into user payment and non-user payment and adopt BOO + BOT model. This project covers a wide range of fields, in order to attract social capital, the construction of specific project may not be carried out by SPV, which is mainly responsible for the top-level design, investment, financing and management. Or, the project is packaged in different fields and promoted by several SPVs in batches. According to the above analysis, the main operation strategies of different kinds of SCPs are obtained, as shown in Table 2.

| Project categories | Features | SPV | Operation models |
|--------------------|----------|-----|------------------|
| Single structure   | Single attribute | SPV is fully responsible for project investment, financing, construction and operation and maintenance. | User Payment: ROT/BOT/BOO Non-user Payment: ROT/BOT |
|                    | Highly professional | Ditto / Do not set SPV | Ditto / DBO |
| Cross structure    | Diversified attributes | SPV is fully responsible for project investment, financing, construction and operation and maintenance. | BOT/BOO BOT+ROT BOT+O&M BLT+BOT/BOO Government construction + transfer +BOT |
|                    | Complex project boundaries | SPV is responsible for the construction of major projects, some of which can be constructed by the government, while others can be constructed by bidding or subcontracting. | |
| Overall structure  | Complex attributes | SPV is responsible for the construction of major projects and other projects are constructed through bidding or subcontracting. | BOT/BOO TOT+BOT/BOO BLT+BOT/BOO BOO+BOT |
|                    | Weak manageability | SPV may not do project construction, mainly responsible for the top-level design, investment, financing, and management; specific projects are tendered or subcontracted by SPV. | |
|                    | Wide range of fields | Package the project in different fields, and advance by multiple SPVs in batches. | |
|                    | High level of sharing | | |

3. Profit-making model of smart city PPP projects
With the operation model determined and the scheme prepared, the PPP project is in its procurement stage. In fact, only focusing on the project’s existing revenue and financial subsidies is far from enough [14]. A feasible profit-making model is an issue of universal concern.

The problem of the profit-making model is analyzed by the problem tree and target tree. Starting with determining the core problem to be solved, the consequences are obtained step by step up, and the causes are found out layer by layer down. Next, the cause and effect relationship described by problem tree is transformed into the corresponding relationship between methods and purposes, so the target tree is established. On the basis of the target tree, path selection is carried out to form a strategy.

3.1. Problem tree analysis of profit-making model
Both practical experience and relative research [8-9] have shown that smart city PPP projects are faced
with the problem of unclear profit-making model. In other words, the core problem here is that the project lacks a feasible profit-making model. By combining the characteristics of smart city, the main reasons for the core problem include:

- **Unreasonable profit distribution.** For instance, unreasonable excess profit distribution generates flawed transaction structures. The main reason is that the “check and balance” of economic benefits under the long-term game between the public sector and private sector and the maximization of comprehensive benefits.

- **The lower business value of “smart” applications.** On the one hand, the enterprise has difficulties in developing appreciation services because of technological immaturity. On the other hand, the enterprise lacks innovation motivation or is stuck in the current business, resulting in low market income.

- **Unreasonable revenue structure.** As Development Report of New Smart City reveals [15], the current concerns about the feelings of residents are still generally inadequate. This, to some extent, leads to a mismatch between the “smart” applications and the residents’ needs, and ultimately evolves into government-dependent payments.

- **Unclear revenue mechanism.** The return of the PPP project is not high [16], so it would greatly affect the survival of the enterprise if there are unclear relevant criteria (e.g., performance evaluation criteria, acceptance criteria).

- **Insufficient “smart” users.** SCPs are high-tech-dependent projects so that residents with the traditional concept are often skeptical, even resist usage of the technology beyond the level of their needs [17].

The above reasons result in many consequential problems. First, the government needs to enlarge its investment and increase operating subsidies, which would increase financial burden and discourage the government from participating in the PPP projects. Second, the commercial return of enterprises falls short of expectations, thus enterprises would withdraw from the field. Third, the project’s weak risk resistance, so enterprises lack the incentive to invest. More importantly, the instability of the expected revenue would lead to the difficulty of the project loan. PPP projects obtain loans by collateralized project assets and expected earnings [18]. After hierarchical division according to the nature of the problems, the problem tree is drawn, as shown in Figure 2.

![Figure 2. Problem tree of the profit-making model in smart city PPP projects.](image-url)
3.2. Target tree analysis of the profit-making model

By target tree analysis, it is found that the aim of smart city PPP project is to establish an effective profit-making model, making the project operate smoothly and obtain a reasonable profit. To achieve the goal, the adopted methods include:

- Innovating benefit distribution structure. With the concept of “check and balance” abandoned by the government, based on social benefits, economic benefits are steadily improved as the starting point, making social capital more profitable.

- Forming a business model of “smart” applications. The enterprise owns the project property right to stimulate it to develop extended services.

- Optimizing revenue structure. With a keen sense of market, enterprises can analyze market demands and deliver “smart” applications as needed, which not only utilizes the resources but also obtains social recognition and more paid users.

- Clearing revenue mechanism. Since the price for software of smart city is difficult to evaluate, the government is supposed to clarify the audit method of input cost of software and effectively controls evaluation error as soon as possible.

- Increased “smart” users. The acceptance of residents by government popularization “smart” concept is improved. Also, the products and services provided by SCPs are oriented to enterprises, so relevant public sectors could mobilize enterprises.

Using the above-mentioned methods, the purposes could be realized, mainly including guaranteeing the target earning rate of the enterprise, improving the efficiency of the financial funding and avoiding additional or excess debt caused by the project. Next, the target tree can be drawn as shown in Figure 3.

![Target tree of the profit-making model in smart city PPP projects](image)

After analyzing the target tree, the corresponding strategy is formed:

- Enterprise Initiation – In the wake of smart city construction boom, the government might make the planning of the smart city in a hurry, resulting in the isomorphism in planning and poor operation effect. In contrast, the enterprise is more market-oriented. According to market demand and combined
with the public welfare characteristics of urban management, the enterprise can initiate strong profitability “smart” applications development projects and bundle non-business projects appropriately, forming the cross structure or overall structural project.

- Enterprise-led – The enterprise layout strategy, with the relevant public sectors and different companies in the same industry to come together for the smart city advice. Given that the SCP belongs to the informatization project, which exists on the traditional infrastructure elements [19], only some of the level II singe items (e.g., urban big data center) involve the land use right. It means that the property of the project is relatively easy to define, thus the property right can be owned by enterprises and BOO is adopted.

- Government-assisted – The SCPs have a high risk. The enterprise can’t rely to single-handedly to carry out SCPs. Anyway, in the enterprise-initiated model, some activities, such as financial support, policy guidance, standard-setting, and franchising all need government participation.

This paper concludes the above strategy as “E-PPP” model, in which “E” represents that the project is initiated by enterprises. Under the “E-PPP” model, the government responsibilities cover: confirming whether the enterprise-initiated projects are in line with public needs, reviewing the feasibility of the project, and making preparing for the plan and monitoring the performance. The responsibilities for enterprises include: predicting the change in market demand, pouring attention to the practical utility of various “smart” applications and avoiding “high-grade”, and undertaking relative responsibilities in each period of the full life cycle of the project. Making full use of respective advantages, the government and enterprise form a joint force to improve the quality of public life and efficiency.

4. Conclusion
Although the hope that PPP model brings to the construction of smart city, it is in the position of problem overlay in practice. In this regard, this paper chooses to address the problems in operation models and profit-making model.

With regard to the matching of operation models, the possible combination models are discussed on the basis of the study on the classification of SCPs, and the different operation strategies of SPV are analyzed. After that, the “E-PPP” model, which represents a profit-making model is established. That is, based on the social benefits, and the steady improvement of economic benefits as the principle, the cross or overall structural projects are initiated by enterprises in the form of BOO model. In particular, the “E-PPP” model is more constructive to the enterprise who expects to connect the brand promotion or product sales with the needs of smart city construction closely. Also, the “E-PPP” model can save the procurement time and avoid the embarrassing situation that no one responds to the government-initiated projects. However, the development of smart city PPP project has a long way to go. How to successfully apply PPP model has many problems worth exploring.

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