Research on the Management and Maintenance of Infrastructures in Fog Section of Motorway based on the MOT Model

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Abstract. Nowadays, a crop of prominent problems like road aging, rebuilding or extending, equipment maintenance and technology upgrading are faced in the management and maintenance of Chinese motorways. With multiple advantages, the infrastructure management and maintenance based on public-private partnership (PPP) model is extensively used at home and abroad. From the perspective of road transportation safety management, this paper discusses the maintenance of infrastructures in state-run motorways with maintain, operate and transfer (MOT) model, analyses its features, and finds problems that should be noticed in implementation plan, implementation steps, and the operating process of MOT project.

1. Introduction
Being a kind of special section in motorways, there is heavy fog in fog section in some periods of time because of elements like topography, climatic and road environment, which may even cause road traffic. Road traffic safety involves people, vehicles and traffic environment. Among which, traffic environment refers to the traffic and transport environment which drivers, passengers and vehicles are in, including the management and maintenance of road. The management and maintenance of traffic environment have large influence on driving safety and the service efficiency of motorways. Let alone the management and maintenance of fog section motorways. In fog environment, the visual range of drivers is limited. If necessary road facilities are damaged at this moment, the coupled superposition may increase the probability of traffic accident. Always locating in intensive sections like mountainous areas, bridges and tunnels, fog sections require higher maintenance cost and quality requirement on facilities because of complex road condition and easily and frequently damaged facilities. With high maintenance requirement and difficult maintenance technology, road sections with high-tech facilities like road meteorological watch system and fog section inducible system need to be maintained by professional companies. Therefore, it is necessary to make in-depth research on maintenance of facilities in fog sections.

The PPP (Public-Private-Partnership-a cooperation model of private enterprises and state-owned enterprises) model has generalized and narrowed meanings[1]. The generalized meaning is the form of
cooperation between government and (profit or non-profit) organizations on certain project, including BOT (Build, Operate and Transfer) model, TOT (Transfer, Operate and Transfer) model, BOO (Build, Own and Operate) model, BLT (Build, Lease and Transfer) model and so on. The narrowed meaning is the model that government and private departments create SPV, which is a kind of special institution, built to introduce social capital, do exploitation, and assumes risks jointly.

In 1992, England firstly applied PPP model to manage public facilities (such as: highway, railway, airport, port, hospital, and jail etc.) and other public immovable properties. There are three stages during the development and perfection process, which are privatization stage, contract signing and contracting stage, and private investment encouraging stage. The research on PPP in China starts a little later. However, certain progress has been got. For example, Chen [2] analysed the connotation and matters needing attention during application; Sha [3] objectively analysed opportunities and challenges of PPP model in China. Deng et al. [4] analysed the PPP model risk sharing principle and the flow of this principle. Lu [5] made deep analysis on PPP model and the development of urban public utilities in China.

There are different attitudes on PPP model in educational circles: Bloomfield et al. [6], Hall [7], Hodge [8], Gaffney et al. [9], Walker [10], Jean et al. [11] keep critical attitude on PPP model, thinking that PPP model does not achieve the effect on public infrastructure required by government in the capital saving. Among which, Hall believes private capital neither eases government’s pressure in financial budget nor provides more infrastructure construction. However, Pollitt [12] keep positive attitude on PPP model. He studied the experience of PPP model in England, pointed out that PPP model in England was able to manage and perform technical improvement of engineering project effectively, and effectively transfer risks of project. The joint management scheme with tradable credits and road tolls for PPP networks was proposed [13]. A transformed first-price sealed-bid auction with independent private values to determine the equilibrium royalties and subsidies in PPP was presented [14].

However, as a whole, most government departments support PPP model. Among which, to confirm the positive and significant function of PFI, England launched PFI: Strengthening Long-term Partnerships in 2006. In 1990, countries like Chile, Portugal and Brazil applied this model, which decreased government’s financial burden, in large scale public infrastructure successively. Therefore, there is much research and application value of PPP model in large scale governmental infrastructure.

Since 2013, China has reinforced the construction of PPP project, inspiring a new round of PPP construction trend in China. PPP project is performed from rail traffic and road traffic construction to maintenance and management in later period. However, the operation procedures of PPP project are different in road traffic construction period and management and maintenance period. Huang et al. [15] studied PPP project in aspects like financing, investment, stock rights, and project management from economic and management perspectives. From highway traffic safety and traffic service quality perspectives, there are relative few researches on management and maintenance of motorways with PPP operation model.

It is not difficult to find that, there are multiple PPP project models with different applicability. The cooperation features of transactions with different models are quite different. Therefore, based on narrowed PPP model, this paper comes up to manage and maintain fog section in motorways with MOT model (maintain, operate and transfer), and discusses the implementation scheme and steps of this model.

2. Main Problems in Management and Maintenance

Main problems in management and maintenance of motorways in current China:

(1) Different maintenance requirements and standards. During the 15 years from 2000, the motorway mileage increased 33.2% every year. With different aging and damaging degree of infrastructures, every motorway has different maintenance requirements and standards. As the increasing of mileage and increasing of construction technology and technological level, old motorways and new ones are maintained by quite different methods, which results in different
maintenance expenditure.

(2) A part of motorways is badly in need of being remoulded and upgraded. Motorways develop along with the development of economy and technology. Along with China’s economic system reform and the speeding up of urbanization, with a series prominent problems like aging road surface, scrapped facilities and unreasonable or unscientific design, many motorways which are built from 1970s to 1980s cannot satisfy current traffic flow and need. For example, some road sections are designed without considering the influence of atrocious weather like heavy fog, ice, strong wind, and high temperature. Traffic safety problems, which are caused by unreasonable designs in long downgrade, tunnel, truck escape ramp, ramp and curve, become more serious along with the increasing of motor vehicle holding quantity in China. The maintenance and upgrade of infrastructure in motorways become more and more urgent.

(3) The pressure of managing and maintaining motorways becomes larger and larger. Motorways in China can be divided into two types according to right of management: state-operated one and private one. The previous type occupies the main portion. According to literature, on the premise of conforming to relevant regulations, China encourages domestic and foreign economic organizations to invest road construction. After regulated period, all Chinese private motorways will be transferred to state-operated ones finally. How can administrative departments ensure the increasing but not decreasing of technical level of motorways when mileages increase constantly? How to maintain infrastructure of highway in time when the vehicle amount keeps rising in China? Obviously, these problems cannot be solved only by traffic management department no matter from financial resources, manpower, material resources, and technical level. At present, there is no research on special maintenance of facilities in fog section of motorways in China.

(4) As shown in Figure 1, the change trend chart of China fog day from 1950 to 2011 shows that the number of fog days in China is increasing. With the increase of fog days, the visibility of expressway is significantly reduced. According to the literature [16], visibility is reduced by about half.

![Figure 1](image.png)

Figure 1  China fog daily variation trend chart

3. Analysis on the Feasibility and Necessity of MOT Model

3.1. MOT model
Belonging to narrowed PPP model, compared with BOT, BOO and BLT models, MOT model lacks construction links in projects, and is mainly used in maintenance, operation and management of fog section in motorways in later period. The project of management and maintenance of fog section in motorways with MOT model is called FRMOT (Fog Region Maintain Operate Transfer) for short, and is called MOT project in this paper. Essentially, MOT project is a PPP project. Except for characteristics owned by PPP project, it also has following characteristics:
(1) Compared with regular PPP project, MOT project requires lesser prior-period investment causes lower financing difficulty to private sectors, and is mainly adopted in the management and maintenance of facilities in fog section in motorways which have been constructed or operated for a period of time.

(2) As the major management and maintenance subject in later period, private sectors’ objective estimation on fog section in existing motorways with current technology is in favour of making scientific and reasonable plan on the management and maintenance. However, the technical disclosure effect with prior-period road construction greatly influences the operation effect of MOT project, and increases operation risks of private sectors. Fog sections and sections without fog in the same road network should be effectively divided. The special fog section in which MOT project will be adopted should be estimated scientifically.

(3) With the major implementation risk of long project cycle which may last for twenty to thirty years, the sustainability of project, stability of support from public sectors, and credit of public sectors are very important. The appearance of fog is greatly influenced by weather. Fog appears in different time and place without discipline in short time under the influence of many factors like time and weather. This requires different demand on periodical maintenance of facilities in fog sections, and increases the difficulty to estimate MOT project in early stage.

(4) Being different from regular PPP project, it is difficult to define MOT project and enact clauses when signing contract. This requires public sectors to supervise MOT projects in later period. However, problems like how to ensure status of public and private department should be solved.

3.2. Difference between MOT Model and Other PPP Models

Except for the features of regular PPP models, compared with frequently used PPP models like TOT and BOO, MOT model has following features. Please refer to table 1. Compared with PPP model, MOT model has low financing difficulty, project operation risk, project risk assessment difficulty, project operation cycle, demand for private enterprises, risk of cost overruns, and market competitive abilities and risk. However, these projects should be done by enterprises with high technological capacity and high economic strength because of its long operation period.

| Content                              | MOT       | Conventional PPP Mode |
|--------------------------------------|-----------|-----------------------|
| Financing difficulty                 | Slightly Lower | High                 |
| Project operation risk               | Easy      | Difficult             |
| Project operation cycle              |           | Long                  |
| Demand for private enterprises       |           | High                  |
| Risk of cost overruns                |           |                       |
| Market competitive abilities and Market risk | Low       | High                  |

3.3. Analysis of feasibility

According to literature [17], the PPP model is most suitable to be used in highway field, which owns relative mature pricing model and process. It is showed by the investigation result that the emerging PPP market has a good prospect and powerful development strength. To assist the development of PPP model, relevant national departments have issued some policies. In the 18th National Congress of the Communist Party of China, “let market play the decisive effect in resource allocation” is proposed. This provides a political and economic environment for the operation of PPP project, upgrading its promotion and application from simple financing cooperation to the level of state economy reform.

PPP projects have been implemented in China from 1990 a. According to data from Bank of Asia, PPP model was used in 1018 projects up to 2011. Please see figure 2 for the specific trend chart.

In China, PPP project can be roughly divided into three stages: a) Foreign companies were in the
dominant position in 1990s; b) State-owned enterprises were in the dominant position from 2000 to 2012; c) China encourages social capitals to participate in the construction of infrastructure from 2013 to now, and raises a new round of PPP trend in the whole China. According to statistical data from the World Bank, China had run 1065 PPP projects (narrowed franchise PPP project) from 1990 to 2012, and had achieved many successes in the construction of public projects with PPP model in fields like motorways, bridges, tunnels, water supply, sewage treatment and power plants. For example: Projects like Beijing No. 4 Subway Project, Quanzhou-Citong Bridge, South Extension Project of Nanjing No. 1 Subway, Shanghai Shenfengjin Motorway Project, and 3rd Nanjing Changjiang River Bridge, have got expected effect to a large extent. With good leading and reference value, Beijing No. 4 Subway Project and Bird Nest Project are the representatives of PPP project up to now. In recent years, Chinese scholars, like Yuan et al. [18] have made in-depth summary and analysis on failed PPP projects or those with problems in China, and found main risks, causes, and inherent laws, providing certain reference value for the successful operation of PPP projects in the future. Domestic scholars including Hao et al. [19], Lu and Ma [20], Yao [21] analysed Beijing No. M Subway Line, which is the first large scale successful PPP project in China, and went depth into its successful experience, providing detailed basis for PPP projects in China in the future.

![Figure 2](image)

**Figure 2** The changing trend of the PPP projects in China

It can be seen, along with the increasing of mileages in China, the pressure in motorway traffic grows every day. It is a good way to effectively ease government pressure and increase management pressure of road traffic through applying PPP model in road traffic safety combining with its features.

### 3.4. Analysis of the Necessity

China reached the goal of road construction, which costs developed countries 50 years, with only 20 years. However, because of rapid development of vehicle industry in China, the increasing of vehicle holding quantity and traffic volume result in coexistence of people and vehicles, traffic jam, frequent occurring of traffic accidents, as well as insufficient maintenance in manpower, financial and material aspects for road infrastructure. The infrastructure which relates to traffic safety becomes a decoration and even the hidden danger.

With construction of motorways being emphasized, the maintenance and upgrade in later period are of more importance. It becomes more unrealistic for government departments to assume this task along with the geometric increasing of mileages of motorways. Governments now maintain and upgrade infrastructures with PPP model as it becoming more mature, which does not only solve the problem of insufficient manpower, financial resources and energy, and drives the reformation of maintenance and management of infrastructure and public facilities [22].

### 4. Research on Management and Maintenance of Motorways with MOT Model

Combining with the operation process of PPP project and features of maintenance of fog sections, the implementation process of MOT projects can be showed in the Figure 3. These projects include 8
steps of project estimation, project bidding, constitution of SPC project company with special targets, SPC financing, maintenance and operation, user usage, user payment, and project transferring. The specific implementation and operation process of every step is showed as follows:

![The MOT project implementation process](image)

Figure 3  The MOT project implementation process

4.1. Bidding of MOT project

With long periods, some even last for several decades, PPP projects have high qualification requirement to private departments or enterprises. Being started late in China, there is no specialized qualification requirement documents of private sectors or enterprises about PPP projects required. Therefore, we may use for reference of experience from England [23 24]. The EC Merger Regulation issued by England government makes clear regulation on financial capacity, company scale, market share, and turnover of private sectors or enterprises [25]. To the MOT projects, the development of private sectors is more important than financial capacity. Company development better shows vitality of enterprises and ensures the survival time of MOT projects.

4.2. Construction of SPC

SPC (Special Purpose Company) refers to public sectors or private sectors/enterprises which operate PPP projects including specific matters like financing and organizing of project operation institutions through organizing specialized agencies. The specific leading organs of SPC might be different according to real demand of MOT project. The mission of SPC terminates when MOT project is completed. During the construction of SPC, the requirements on MOT projects from public sectors should be defined to ensure the quality and quantity of MOT project. To not influence the function of SPC, public sector should not participate in too much during the operation of MOT project. When maintaining infrastructure in fog section in motorways, SPC needs to ensure timely and effective maintenance, efficient supervision, and avoid unnecessary intervention from administrative departments in technological innovation and renewal of infrastructure. At the same time, fog sections always locate in high mountains, gorges and network of rivers where there are many bridges, tunnels, and complex roads, which require high qualification requirements on SPC companies because of difficult technical maintenance and frequent maintenance.

Most MOT projects have long time of duration. As to the maintenance of infrastructure in motorways, SPC might survive until the scrapping of motorways when private sectors gain considerable benefits and develop well. Therefore, public and private departments should regulate obligations and rights of SPC, public sectors and private sectors in contract form at the beginning of preparing SPC, trying to regulate all issues like personnel and capital during operation in contract. Anything may happen during the implementation of contract because of long periods (some even last for several decades) of MOT project. It is believed by some scholars that there should be a mid-term contract to modify contract when it is needed.
4.3. Financing of MOT projects

One of the largest advantages of PPP model is to spread risks effectively [26] and solve government’s shortage of funds in the construction of large scale public infrastructure. In 2014 a, Wang Baoan, the vice-minister of Ministry of Finance pointed out that “the expired repaying debts of local governments occupy 21.89% of overall debts”. At present, the urbanization rate in China is 53.6%, and this rate is predicted to be 60% in 2020, which will bring investment demand of RMB 4.2 billion. According to operation experience of foreign PPP projects, capital problem is the decisive problem in MOT projects after SPC being organized by public or private departments.

4.4. Existing problems and advices during the implementation of MOT

The reasons for which infrastructure of fog section in motorways being damaged are divided into: man-made destruction and non-artificial destruction. As shown in Figure 4, the proportion of damage to equipment caused by different environmental factors is shown. Man-made destruction contains: deliberate stealing, smashing, road accident, jerry-building during maintaining, as well as unqualified infrastructure or those cannot be used because of not operating according to procedure. Non-artificial destruction contains: natural depreciation and abrasion, corrosion because of light and air, as well as other non-artificial factors, environmental climates. Different damaging ways determine different maintenance methods and costs.

![Figure 4](image_url) The proportion of equipment damaged by different environmental factors

The aging degrees of infrastructures in fog sections are different because of different time, period, traffic flow, and external environment. MOT projects should be estimated according to different fog sections and using conditions of facilities, and equipped with different maintenance schemes and grades. The returns to scale and range benefits should be considered when estimating MOT project for fog section. Before maintaining infrastructures in motorways, public sectors should firstly make professional subsection and subitem estimation on facilities in fog sections, confirm their service life period, depreciation condition, the natural environment and traffic condition, record road facility conditions, make scheme and expense budget for maintenance or upgrade schemes on this basis, and lay foundation for bidding in later period. Following problems should be solved during the implementing of MOT projects:

1. How can public sectors and private departments (or enterprises) cooperate effectively and complement each other’s advantages. Table 2 is the simple comparison of public sectors and private sectors that make construction of infrastructures in motorways on 7 aspects like national policies, information resources and capitals. It can be seen from Table 2 that public and private sectors are able to complement each other’s advantages. However, it is worth thinking deeply about how to do this during the implementation process. The managing and delegating powers to lower levels and playing positive functions of government during implementing process of MOT projects are the key to the
success or failure.

| Sector       | National Policy of Information Sources | Fund Experience | Management Efficiency | Initiative and Innovation | Risk Appetite | Stability of Decision making |
|--------------|----------------------------------------|-----------------|-----------------------|--------------------------|---------------|------------------------------|
| Public sector| Fast                                    | Shortage        | Low                   | Low                      | Low           | Low                          |
| Private sector| Slow                                    | Adequate        | High                  | Low                      | Low           | Low                          |

(2) Project risk impacts the investment activity of private sectors.

The non-uniform revenue time, standards and acceptance standards of MOT project increase investment risk Zheng (2015). Meanwhile, as the authorities in China, public sectors cannot cooperate with private sectors (or enterprises) equally or effectively because of unequal administrative status. Private sectors (or enterprises) are always in the weak position and lack enough right of speech. On the other hand, because of long period, the personnel change of both parties may decrease the constant stability of projects and increase risk. MOT project also has problems in PPP projects.

The Quanzhou-Citong Bridge Project is a typical sample [27]. This is the first BOT project for construction of infrastructure which adopts private capital in China. It was constructed in trial in 1993 a, and was open to traffic in 1996 a. It was said by the person in charge that the invested capital has not been returned until 2014 a mainly because there is no effective and substantial agreement between the enterprise and local government. Most investment risks are assumed by the enterprise. The failure of this project influences domestic PPP projects, and makes a part of enterprises dare not to cooperation with governments on these projects later. Therefore, the research team of Li and Shen [28] puts forward 9 principles about risk distribution based on long term research. At the same time, PPP projects develop rapidly in recent years in China because of political support from governments.

(3) Imperfect policies and systems

From 2013 to now, the government of China has issued a series of documents and regulations on PPP projects, while they are still insufficient in operation because of its complexity. For example, there is still no standard model for how to effectively standardize contracts signed between public and private sectors based on PPP projects. During actual operation, public sectors, like the municipal government of Chongqing, call up specialists to discuss and try to refine contract terms. This operation avoids contract risks to the largest extent. However, risk brought by imperfect contract is still very large. The selection standards of private sectors, such as qualification of assuming PPP projects, are not required by specific documents. In academic circles, scholars are divided into two parties. One side recommends governments to strictly examine qualification of private sectors, rigorously enforce market access, and require enterprises who be responsible PPP projects to have high-growth and powerful economic strength. Another side keeps the opposite opinion, believing that governments should decrease market access for private sectors and let more enterprises to participate in PPP projects.

This MOT project for maintenance of infrastructure in fog section in motorways discussed in this paper costs a large number of capital and long period. As to enterprises with poor anti-risk capability, the operation cost and risk will be increased if these enterprises close down or have capital problem during the contract period. Most PPP projects have similar demands with MOT project. Therefore, the government of China should improve technical specification and legislative guarantee of MOT projects to provide laws to be abided by and based on.

(4) Unstable decisions of local governments

From implementation condition of PPP projects in recent years, the condition of “one side wishful thinking and another side little reaction” exists between public and private sectors. Governments want
more private companies to participate in the bidding of PPP projects, while private enterprises give little reaction. The reasons are the long implementation period and variable and random decisions made by local governments. For example, the phenomenon of “making frequent changes in policies” and “employees change when leaders change” exist in some local governments, which make many MOT projects going broke. Withal, it is pointed by Wang and Feng [29] that “government credit” is one of major reasons which influence the success or failure of PPP project. This requires government to protect projects from executive ability perspective to ensure projects not being influenced by change of the term of government or personnel and projects being driven constantly by specialized institutions.

5. Conclusions
From the perspective of traffic safety management, with MOT model, this paper analyses the feasibility and necessity to maintain infrastructure in motorways when state-owned motorway quantity increases, and problems like aging, reconstructing (expanding), facility maintaining, maintaining, and technical upgrading of a part of motorways, especially fog section (including state-run ones or ones transferred from private ones) become more serious. It comes up with following conclusions:

1) The traditional PPP model analyses from perspectives of project management, investment and financing, while MOT model adopted in motorways analyses from perspectives of fog section in motorways and traffic safety management.

2) Being compared with traditional PPP project, MOT model has features like low financing difficulty in early stage, clear implementation target, and risk sharing.

3) MOT model has advantages like professional technology and detailed project subdivision which are not owned by traditional PPP model. However, being the same with traditional PPP model, it has the same problems like large risks in later period and government credit. Therefore, a good environment in governmental level should be created.

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