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A Framework for Implementation Public-Private Partnership in Roads' Maintenance and Operating Projects in Jordan

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Abstract: This paper describes a systematic approach to assess and fund highways infrastructures project in Jordan. In essence, it focuses on building a framework to implement Public-Private Partnership (PPP) in roadways' Maintenance and Operating (M&O) projects. It presents a methodology to assess the conditions of the highway infrastructures using structural and functional indices. The deterioration in the infrastructure condition with the age is presented, followed by M&O project period classification. Subsequently, identifying the problems confronted in the PPP (M&O) process and the associated factors affecting PPPs in service delivery, and proposing activities contributing to improvements of the M&O performance with the implementation of PPP. Thereafter, a framework to implement the PPP in highway maintenance projects is presented.

Keywords: Highway maintenance, Pavement condition index, Public-private partnership

Introduction

In the contemporary era, transportation assets face a significant challenge due to the escalating demand for traffic. The continual growth in demand results in the deterioration of infrastructure, necessitating maintenance and operation under acceptable conditions. Globally, transportation agencies grapple with the limitation of budgets for maintaining and operating their infrastructure. It has been proven that increasing the capacity of infrastructure is not a viable solution to accommodate traffic demand, especially in densely populated urban areas where space is restricted.

The future planning and vision for the transportation sector address issues such as resource optimization, restricted capacity augmentation of infrastructure, increased traffic due to population growth, declining revenue sources, reduced availability of conventional fuel, and heightened congestion on roadways. Traditional sources of income for highway management include fuel tax, road tax, vehicle registration fees, parking fees, and tolls on certain sections of the infrastructure. However, in developing countries, highway management income depends on dedicated budgeting from authorities like the Ministry of Public Work and Health (MOPWH) or other municipalities. Additionally, external funds from different countries and agencies are often sought to promote infrastructure development. Therefore, the development of a maintenance and operating plan is essential, based on a systematic assessment of road conditions.

One successful model for funding public projects is Public-Private Partnerships (PPPs). PPPs serve as a funding source for highway infrastructure when the government faces financial constraints or funds are unavailable for spending. An exemplary case is the state of Indiana, which received $3.8 billion from a private entity to operate and upgrade its toll roads in exchange for toll revenue over the next seventy-five years (TOLLROADSnews, 2006). Governments can overcome various restrictions, such as legislative constraints and budget allocations, by engaging in PPPs with the private sector to undertake projects that might otherwise be challenging to implement (Engel et al., 2009).

While successful examples of PPPs exist, there have also been instances of misplacement of structure and risk allocation leading to contract failures, renegotiations, or complete breakdowns. For instance, the Dulles Greenway project in Virginia defaulted in its early years due to an overestimation of road demand. Inflexibility in contract structures to accommodate unforeseen circumstances also contributed to failures, as seen in the case of Orange County SR91, where a non-competence clause led to the failure of the PPP. In Jordan, the Queen Alia International Airport (QAIA) stands as the first airport in the Middle East operated under PPP. QAIA received a 25-year concession contract to reconstruct a new terminal, which was opened in 2013 (Biygautane & Jarrar, 2023).

Jordan has predominantly utilized PPPs for energy generation, with few critical infrastructure projects in other industries. The first PPP project in Jordan was the 1995 feasibility study to build the Samra Wastewater Treatment Plant on a PPP basis, although its execution was delayed until 2003 (Oxford Business Group, 2015). Following geopolitical issues like the 2003 Iraq War and the 2007 financial crisis, which strained public finances, Jordan expedited its adoption of PPPs to secure private funding for infrastructure projects (IMF, 2017). The Jordan Education Initiative, the first PPP in MENA education, was implemented in 2003 (Mistarihi et al., 2012). PPP contracts have been awarded for energy, water, sewerage, an airport, a port, and an ICT project, totaling over $7 billion in Jordan. The World Bank Group (2021) reports that 46 projects worth $10,563 have closed. The IMF (2017) estimates that 30% of Jordan's public investment portfolio was procured through PPPs, a significant contrast to 6% in other emerging nations. However, 70% of these contracts, predominantly in the power or water sectors, are government-funded, necessitating government or State-Owned Enterprise (SOE) payments during operation (IMF, 2017). Such agreements transfer most of the risk of early termination or inefficient performance to the government and fail to generate end-user income, thereby increasing the burden on the public budget for project funding.

To this end, this paper aims to develop a framework to implement the PPP in roads' maintenance and operation projects. In essence, this study contributes significantly to state-of-art and state-of-practice by developing a framework to implement the PPP in roads maintenance and operation in Jordan. The developed framework provides an in-depth into how maximizing social benefit, higher quality of service, transparency, and achieve the efficiency in private sector. The proposed framework helps decision makers to foster the rapid development of PPP projects. Following this introduction, the next section presents a thorough review of the road's infrastructure assessment, and the different PPP types. The research methodology/approach is also presented in Section 3. The fourth section discusses the developed framework. The last section elaborates on the implications of the research and presents conclusions, limitations, and recommendations for future research.

Settings

In this section, Public Private Partnership (PPP), the roads infrastructure assessment, followed by the operation and management period and the different PPP types are presented.

Public Private Partnership

There are many types of structures for a PPP, but the primary categorization is based on the type of infrastructure being considered for the PPP venture, i) Existing infrastructure and ii) New infrastructure. When dealing with a delivery structure for existing infrastructure it is labeled as i) Brownfield project which would be the operation and maintenance of an existing asset, while for the development and construction of a new infrastructure it is labeled as ii) Greenfield project. Traditionally the type of contract that has been followed is the design-bid-build, wherein the agency designs the asset by means of in-house staff or external contractors and then bid the project for construction. This traditional arrangement ensures that the design risk, along with the operation and maintenance is retained by the agency while the construction is carried out by an external contractor. Though with time there has been a change in the terms of these traditional contracts to ensure the quality of construction, in the form of performance guarantees for a specific period of time after the construction is finished. The two general types of innovative contracting techniques are for i) non-traditional form of project delivery and ii) project having some form of private debt or equity investment.

Several works have been done to identify the critical factors that affect the implementation of PPP in M&O projects. Hwang, Zhao and Gay (2013) studied cases in Singapore and identified 42 risk factors and 14 factors affecting success of PPP projects. Those factors were assigned to the government authority and the private sector. Similarly, in another research, critical risk factors in the PPP projects were grouped into four aspects referring to economic, institutional, social and industrial, and project-specific factors (Jin & Zhang, 2011). The most relevant factors are presented in Table 1.

Table1. Factors affect PPP implementation

Group	Factor
policy and governance structures	instability caused by government changes. immaturity of relevant legal system. unsatisfied distribution of risks and responsibilities between private partner.
obstacles in operating stages	lack of technical experience. lack of experiences in M&O long term projects.
financial factors	limited market demand financial risks

Road Infrastructure Assessment

The deterioration in facility condition can be mainly categorized into two types: functional deterioration and structural deterioration. Structural condition assesses the infrastructure's capacity to withstand traffic loading, while functional deterioration gauges the quality-of-service provision. Roads' infrastructure, including pavement and bridges, experiences wear and tear with the passage of traffic. The degree of deterioration depends on various factors, such as pavement material, traffic volume and type, and weather conditions. Extending the life of infrastructure involves implementing preventive maintenance before reaching the minimum acceptable pavement performance, as pavement performance starts high and degrades over time.

Common deterioration figures suggest that during 75% of pavement life, pavement performance degrades by 40%. In the second phase, this degradation occurs by only 12% of the pavement lifespan (Johnson, 1983). George et al. (1989) developed a model predicting pavement deterioration, factoring in variables like traffic load, pavement age, strength, and condition. In Jordan, pavement sections predominantly consist of flexible pavement. A predictive model for pavement deterioration in Jordan was developed by Al-Suleiman (2021). Their results indicated that the majority of pavement sections were in an acceptable condition, as per pavement evaluation. However, according to proposed Maintenance and Rehabilitation (M&R) strategies for Jordan's rural roads, around 40% of the evaluated pavement sections require rehabilitation.

Pavement condition is often assessed based on surface condition, expressed by pavement distress that quantifies the impact of traffic loading, environmental effects, and material characteristics. The rating method provides an index reflecting pavement distress in terms of severity, extent, and type of distress as both structural and functional faults. The surface condition is measured by the number, type, extent, and severity of cracks on the pavement surface, which are then summed up to calculate a deducted value from the ideal pavement condition. The quality of driving on the pavement is expressed by the roughness index, influenced by longitudinal and transverse cracks. Both crack roughness and other indices are used to evaluate pavement projects. Evaluating a pavement network requires a predefined minimum acceptable level for pavement condition, usually based on the pavement condition index (PCI) for each roadway. These values are then compared and prioritized based on the lower PCI.

In the United States, several agencies have developed an index to measure pavement condition based on distress or condition, known as the pavement quality index (PQI). For example, Ohio DOT uses pavement condition rating and pavement roughness index to calculate RQI, while Minnesota employs Pavement Riding Quality to calculate the PQI. Nebraska DOT relies on the serviceability index to calculate the PQI, where a combination of visual distress and rut depth or faulting is considered (FHWA, 2013).

Combining PPP in M&O Projects

In identifying the different factors affecting the implementation of PPP in M&O projects, the most critical stage is having obstacles during the operating stage which can be mitigated by enforcing the performance-based contract scheme. Performance-based road maintenance by contracting (PBRMC) is a method under which a contractor has to plan, design, and implement maintenance activities in order to achieve short- and long-term road condition standards for a fixed price, subject to specified risk allocation (Frost and Lithgow, 1998).In essence, the performance based contract shows its ability in reducing maintenance costs through the application of more effective and efficient technologies and work procedures; providing transparency for road users, road administrations and contractors with regard to the conditions roads have to be maintained; improving control and enforcement of quality standards; and improving overall road conditions. The issues of implementing the PBC has been identified as follows: having performance specification and setting up a standard, expertise of the private sector, deciding the initial project, risk exposures, performance monitoring, employee issue, payment, and termination of the contract.

Performance indicators measure the performance of the contractors in PBMC. Some examples of performance indicators/standards. Commonly, the International Roughness Index to measure the roughness of the road surface, which affects vehicle operating cost; absence of potholes and control of cracks and rutting, which affects safety and pavement performance which could be measured using PCI ; amount of obstruction of the drainage system to avoid destruction of the road structure; friction between tires and road surface for safety reasons; and retro-reflexivity of road signs and markings for safety reasons.

Results

In this section the framework of implementing the PPP within the M&O projects is presented. To implement the PPP within the M&O projects, two main items should be assigned. The contract authority and the public responsibility, the framework is presented in Figure 1.

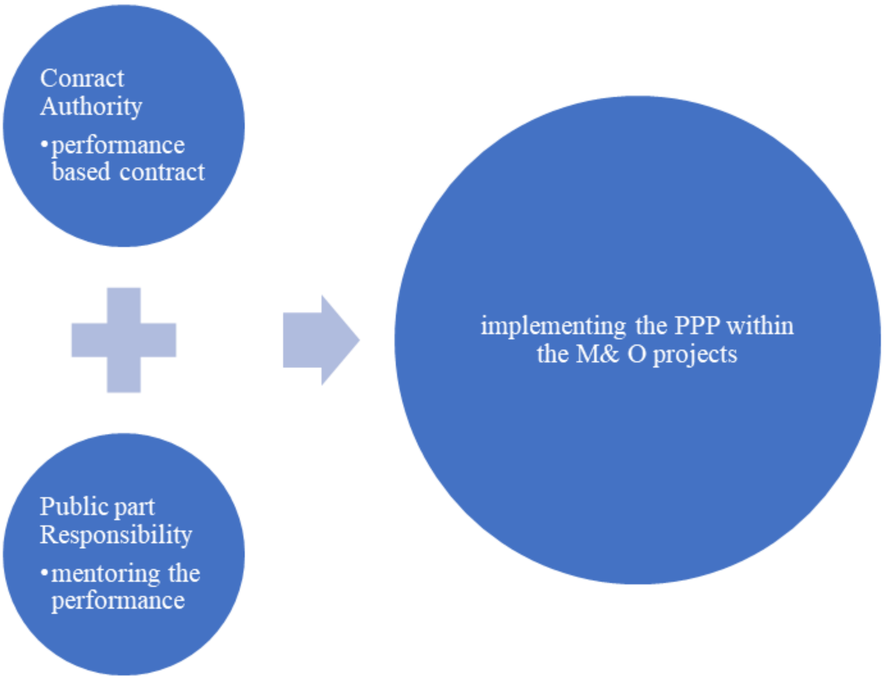


Figure 1. Framework of implementation of PPP within M&O projects

Contractual Authority

In identifying the contractual authorty, assigning the propoer contracutal authority type is the first step. Before implementing the PPP understanding the difference between the different PPP types is presented here. Innovative structures for contracts are i) Design and Build, ii) Design-Build-Operate-Maintain, iii) Cost-plus-time bidding (A+B) contracting, iv) Construction Manager/General Contractor, and v) Construction Manager at Risk. The Innovative financing structures are i) Design-Build-Finance-Operate, ii) Build-Operate-Transfer, and iii) Long-term Lease Concessions. The first type of contract, the design and build require the contractor to assume both design and construction and the associated risks, while the public agency pays for the venture by a pre-decided payment structure. The Design-Build-Operate-Maintain type of contract demands that the contractor not only design and build, but also operate and maintain the asset for a predetermined contractual time. Another variant of the contract structure is A+B which has an objective of minimizing the delivery time for projects with priority for fast completion, as in the case of urban and congested areas. The Construction Manager/General Contractor is most suited for speedy bridge construction, by means of hiring two separate contractors for design and construction, but with the control of design lying with the public agency. The Construction Manager at Risk type of contract requires the need of a contract manager and a design contractor, and then the client and construction manager negotiate a contract as the design process progresses, facilitating better understanding and team relations over the process (NCHRP,2009). The different PPP types, which can be implemented within M&O, are summarized in Table 2.

Table 2. PPP contract types in M&O projects

Type	Subtype	Operating and maintenance
Operation and maintenance (public ownership of the facilities)	Management contract Lease contract	Private investors do not have ownership, but they are responsible only for the risk associated with the M&O over a short time (e.g., 3-5 years)
Concessions (public ownership of the facility)	Rehabilitate-operate transfer Rehabilitate-lease/rent-transfer Build-rehabilitate-operate-transfer	Private investors do not have the ownership rather they are responsible for the M&O risk over a long period (e.g., 20-130 years)
Greenfield projects (private ownership of the facilities)	Build lease transfer Build operate transfer Build own operate Merchant Rental	Private investors have ownership over a long period (e.g., 20-30 years) and are responsible for building operating and maintaining risk during this period.
Management and lease contracts	Management contract: transfer responsibility for managing a utility to a private operator, often for three to five years. Lease contracts: an operator is responsible for operating and maintaining the business, but not for financing investment.	
Concession contracts	Rehabilitate-operate-transfer (rot): a private sponsor rehabilitates an existing facility, then operates and maintains the facility at its own risk for the contract period. Rehabilitate-lease/rent-transfer (RLT): a private sponsor rehabilitates an existing facility at its own risk, leases or rents the facility from the government owner, then operates and maintains the facility at its own risk for the contract period. Build-Rehabilitate-Operate-Transfer (BROT): a private developer builds an addon to an existing facility or completes a partially built facility and rehabilitates existing assets, then operates and maintains the facility at its own risk for the contract period	
Greenfield projects	Build-lease-transfer (BLT): a private sponsor builds a new facility largely at its own risk, transfers ownership to the government, leases the facility from the government and operates it at its own risk, then receives full ownership of the facility at the end of the concession period. Build-operate-transfer (bot): a private sponsor builds a new facility at its own risk, owns and operates the facility at its own risk, then transfers the facility to the government at the end of the contract period. Build-own-operate (boo): a private sponsor builds a new facility at its own risk, then owns and operates the facility at its own risk. Merchant: a private sponsor builds a new facility in a liberalized market in which the government provides no revenue or payment guarantees. The private developer assumes construction, operating, and market risk for the project rental: a private sponsor places a new facility at its own risk, owns and operates the facility at its own risk	

Mentoring the Performance

Pavement performance in its service life cycle is the manifestation of combined effects of traffic loading and non-load factors concerning pavement type, age, climatic features, subgrade material characteristics, drainage conditions, construction quality, and rehabilitation and maintenance treatments. Conventionally, the pavement surface condition for a highway segment can be measured by the present serviceability index (PSI) or pavement condition index (PCI) which is established on the basis of roughness, cracking, and rutting measurements. The pavement performance trend can be assessed using PSI or PCI values against the cumulative ESALs in its service life-cycle. The PSI or PCI values can be measured according to the pavement design curve and field performance curve, respectively. The area between the horizontal, zero-deterioration line and the design curve in terms of PSI-ESAL or PCI-ESAL losses represents the portion of pavement condition deterioration caused by pure traffic loading (portion a). The area between the design curve and field performance curve as PSI-ESAL or PCI-ESAL losses represents the portion of pavement condition deterioration caused by pure non-load factors (portion b), as well as the load and non-load interactions that can be further split into load-related interaction (portion c) and non load-related interaction (portion d). As such, the overall load portion of pavement condition deterioration is the summation of pure traffic loading and load-related interaction portions (portion a + portion c). Practically, the pavement design and field performance curves and a proportional rule can be employed to derive the individual portions of pavement deterioration (Fwa and Sinha, 1987). Based on the method described in the above, the design curve and field performance curve involving rehabilitation and maintenance treatments can be used to establish the load and non-load portions of pavement rehabilitation and maintenance cost. Similarly, the design curve and field performance curve involving rehabilitation treatments only can be utilized to establish the load and non-load portions of pavement rehabilitation cost. Then, the load portion of the maintenance cost can be computed as the difference between the load portion of pavement rehabilitation and maintenance cost, and the load portion of pavement rehabilitation cost. The ESAL-based and VMT-based/PCE-MT-based procedures can be utilized to separately estimate the shares of load and non-load related pavement rehabilitation cost or maintenance cost attributable to each category of vehicles. The proportionality assumption is illustrated in Figure 2.

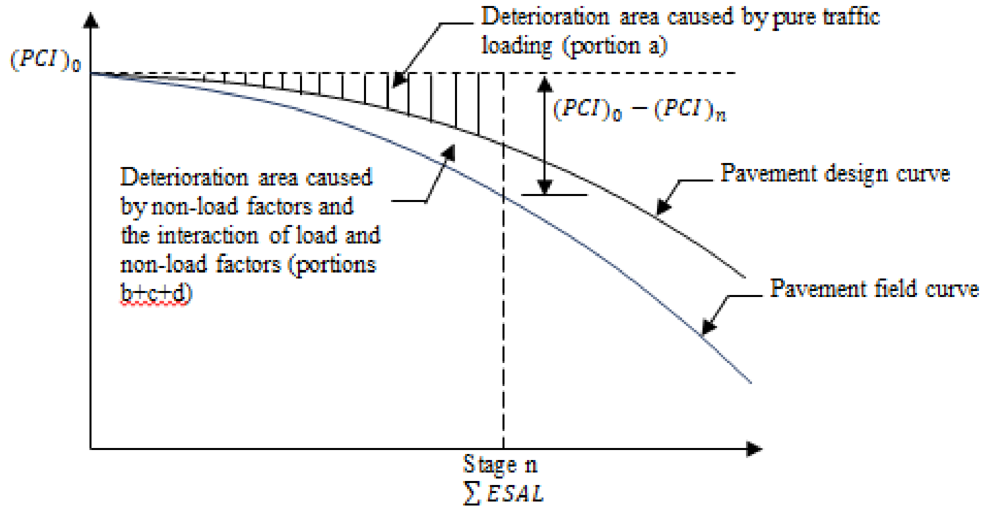
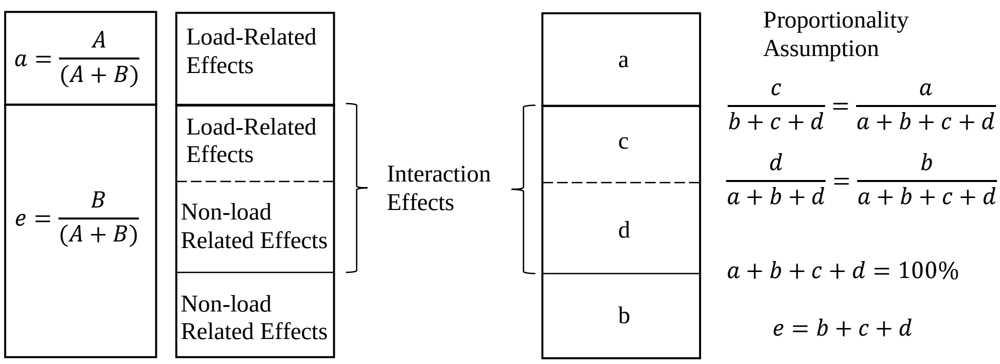


Figure 2. Representation of load and non-load factors shares on pavement condition deterioration

The computation of load and non-load factors on pavement performance is illustrated in Figure 3 below



Note: A = area between horizontal line and design curve as PSI-ESAL or PCI-ESAL losses
B = area between design curve and field curve as PSI-ESAL or PCI-ESAL losses

Figure 3. Computation of load and non-load effects on pavement performance

Annual Pavement Maintenance Cost Models for Traffic Loadings

Small et al. (1989) developed the model of maintenance cost for annual ESALs by first determining the overlay interval T as a function of annual traffic loadings Q and number of ESALs that cause pavement to wear out before requiring an overlay N, follow Paterson and Newbery assumption that pavement roughness grows linearly with cumulative ESALs and exponentially over time. The formulation for estimating T is calculated as

$$T = \frac{N}{\lambda Q} e^{-mT} \quad (1)$$

where,

Q: Annual traffic loadings
m: Pavement deterioration rate.
N: Number of standard axle passages before requiring an overlay.
λ: The fraction of one-directional axel passages travelled.
The present value of total pavement maintenance costs during its life cycle is then can be estimated by converting infinite sequence of maintenance cost C every period of T year to present value with a discount rate of r

$$M(Q, W, D) = \frac{C}{(e^{rT} - 1)} \quad (2)$$

The annualized maintenance costs given discount rate of r is estimated as rM.
Marginal maintenance cost for traffic loadings
The model of marginal pavement maintenance cost for traffic loadings is derived by differentiating annualized maintenance cost with respect to annual ESALs

$$MC_m = r\frac{\partial M}{\partial Q} = r\frac{\partial M}{\partial T}\frac{\partial T}{\partial Q} = \frac{r^2 e^{rT} C(W)}{(e^{rT} - 1)^2}\frac{\partial T}{\partial Q} \quad (3)$$

With T is estimated by Eq. 3, we can find $\frac{\partial T}{\partial Q}$ by differentiating both sides of the equation with respect to Q, corresponding to the case where pavement deterioration rate m is 0 and is not 0. Finally, the marginal pavement maintenance cost of annual ESALs without considering growth of annual ESALs is derived as

$$MC_m = \begin{cases} m = 0, (\frac{(rT)^2 e^{rT}}{(e^{rT} - 1)^2}) MC_m^0 \\ m \neq 0, (\frac{(rT)^2 e^{rT}}{(e^{rT} - 1)^2})(\frac{e^{mT}}{1 + mT}) MC_m^0 \end{cases} \quad (4)$$

PPP in M&O project Framework

In Jordan, to enhance public-private partnership institutions and policies (PPPs) Government, the Jordanian government and the Public-Private Infrastructure Advisory Facility (PPIAF) funded the definition and establishment of a PPP Unit inside the Ministry of Finance, suggestions to strengthen the legislative and regulatory framework for PPPs, a PPP policy, and a pipeline of priority PPP projects. The proposed framework is shown in Figure 4 below.

Discussion

This study provides a framework which will help standardize the practice of PPP in highways maintenance and operation projects. The framework discusses the different types of the PPP contract and the performance-based contract as such, public and private sectors can be beneficial from this study. This accelerate the development and progress of Maintenance and operation projects and ensures that practices are in line with international standards.

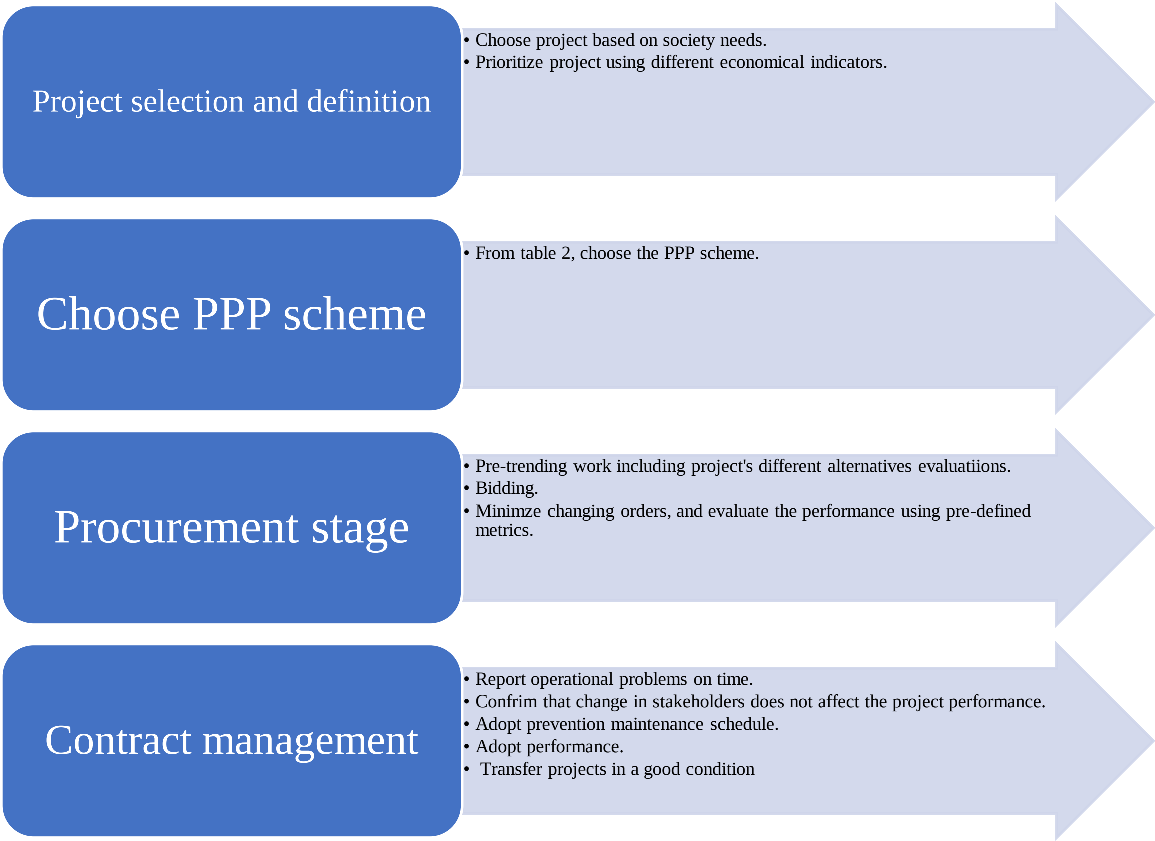


Figure 4. PPP Framework for M&O projects

Initially the framework starts withproject identification and thorough feasibility studies should be done at the PPP initiation stage. Local practitioners should engage opposition political parties and external stakeholders extensively. Transparency is vital in the second PPP stage. Fairness and competitiveness in PPP contract awarding should be ensured. Investors must follow output standards and the contracting authority must oversee the third stage of the PPP process. Private investors should use local materials and prevent building delays. The private partner should prioritize reliable and efficient service delivery at the end of the PPP process. The contracting authority should regularly monitor private partner performance. This suggested framework also gives a framework to standardize PPP in Jordan using different performance indicators including PQI and OCI, also using theoretical backgrounds in predicting the infrastructure conditions using either global standards from FHWA (FHWA, 2007) or using local studies.

This would speed up PPP projects and ensure international standards. The best practise framework provides a th eoretical foundation for developing meaningful hypotheses for empirical research. This approach could be appli ed to a Jordanian or other developing nation project to test its efficacy and efficiency. Finally, the best practice framework serves as a theoretical framework for the formulation of relevant hypothesis for further empirical research. Essentially, the framework could be adopted and tested on a real case project in any developing country to examine its effectiveness and efficiency.

Conclusions

This paper developed a framework for PPP implementation in highway M&O projects. The outputs of this study considerably informs local practitioners in developing countries particularly in Jordan of the best practices that should be carefully observed at M&O projects when implementing PPP projects. In addition, this study expands the existing but limited knowledge on the effective ways of practicing PPP for construction projects in Jordan and developing countries in general. It is hoped that local practitioners in developing countries particularly Jordan, will employ the best practices proposed at each stage of the PPP process in order to ensure a successful PPP implementation and also expedite the implementation of construction PPP projects.

Certainly, a large number of publications would have helped increased the number of best practices. However, considering that the PPP practice is not implemented in Jordan and the fact that few researchers have contributed to PPP discussions using performance-based contract. Nonetheless, the identified best practices should be validated with guidelines issued by the World Bank and state-of-art, thus the results are valid for future reference. Another major limitation is that the best practice framework was not validated using real projects. Apparently, this would have given better assessment results of the validity of the framework. It is suggested that future research studies should adopt the best practice framework and test it on a PPP project throughout its performance-based contract. The outcome of the project that followed the best practice framework should be compared with projects that did not follow the best practice framework. Alternatively, the best practice framework can be tested on a well-established successful PPP project. The applicability of the best practices at each stage can be evaluated by project participants on a Likert scale.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the author.

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