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PUBLIC-PRIVATE PARTNERSHIP NATIONAL PROGRAMS THROUGH THE PORTFOLIO PERSPECTIVE: A SYSTEM DYNAMICS MODEL OF THE UK PFI/PF2 PROGRAMS

Public-Private Partnerships (PPPs) have been adopted by numerous countries to alleviate fiscal pressures and transfer responsibilities to the private sector. However, the long-term sustainability of this procurement mechanism is uncertain due to social and economic limitations. This study aims to provide valuable insights for PPP decision-makers by analysing the long-term social and financial implications of one of the largest PPP programs globally – the PFI and PF2 programs in the UK, consisting of over 700 projects – from a portfolio perspective using System Dynamics. Our research identifies the key relationships driving the interaction between PPP development, societal concerns, and financial constraints. Causal-loop diagrams are developed to elucidate the causal structures within the system and estimate the long-term financial effects of PPPs on the government and society. The analysis revealed three relevant weaknesses that have led to the eventual closure of the PFI program in the UK, namely, high costs and long-term profitability of private investments in the long-term; the occurrence of recurrent cost and time overruns, and the lack of transparency that raised concerns about the program accountability.

Keywords: dynamic models, influencing factors, PPP program, private finance initiative, stakeholders.

INTRODUCTION

PPP projects are contracts between public authorities and private sector partners who design, finance, build, and manage public services such as health, education, and transportation (Amadi, Carrillo and Tuuli, 2018; Castelblanco *et al.*, 2022; Rojas *et al.*, 2023). These contracts typically span between 25 and 30 years and are signed with "special purpose vehicles" (SPV), which bring together private construction, facility management, and financing companies (HM Treasury, 2020; Marcellino, Castelblanco and De Marco, 2022a). This project delivery has been embraced by several countries

around the world because of the benefits derived from a life-cycle perspective of projects taking advantage of the innovative, managerial, and funding capacities of the private sector (Castelblanco and Guevara, 2022).
The UK government's adoption of Public-Private Partnerships (PPP) has been a significant policy development for the past three decades. The two main forms of PPPs implemented in the UK were the Private Finance Initiative (PFI) and the Private Finance 2 (PF2), which aimed to reduce public sector fiscal pressure and transfer responsibilities to the private sector. PFI was introduced in 1992 (Hodges and Mellett, 2012) to improve the public sector's infrastructure through private sector investment and expertise (Villalba-Romero and Liyanage, 2016). PF2 replaced PFI in 2012 due to concerns over value for money (HMT, 2016). PFI allowed for a financial mechanism to obtain private finance without affecting public borrowing and created new investment opportunities for finance capital (Grout and Stevens, 2003).

The UK government implemented 704 PPP projects under PFI and PF2 with a capital value estimated at £57 billion. However, the estimated payment over 30 years was £188.35 billion, leading to concerns over the high cost of these projects (HM Treasury, 2020). The termination of PFI projects was announced in 2018, mainly due to the political opposition and the potential for inefficient management of assets when the government takes over from private entities after 25/30 years (HM Treasury, 2020).
This paper aims to analyse the long-term social and financial implications of one of the UK's largest PPP programs from a portfolio perspective using System Dynamics (SD). SD has been used previously to assess national PPP programs' financial and social management strategies (Pagoni and Patroklos, 2019) to forecast demand in PPP projects (Oloruntobi Dada, 2013), and analyse the impacts of financing strategies on government and private investors' needs (Zhang, Hou and Qian, 2020).
This paper aims to contribute to the existing body of literature by providing insights into the causal relationships driving the interaction between PPP development, societal concerns, public policy, and financial constraints. Causal-loop diagrams will be developed to explain the causal structures within the system and estimate the long-term financial effects of PPPs on the government and society. The findings of this research will provide valuable lessons for PPP decision-makers worldwide and offer governments suitable policies to enhance the outcomes of their infrastructure portfolios.

METHODOLOGY

SD was chosen as the overarching methodology to analyse the long-term social and financial implications of the PFI and PF2 programs in the UK from a portfolio perspective. To do so, firstly the SD model was defined according to the goal previously established. The next steps were the creation of the Casual Loop and the Stock and Flow Diagrams respectively. The Casual Loop Diagram, the Stock and Flow Diagram, and the corresponding quantitative simulations have been created in Vensim, which is a system dynamics-based software.
The methodology used in this study is SD, which was introduced by Forrester in the 1960s as a modelling and simulation methodology for dynamic management problems (Sterman, 2000). SD model consists of Causal Loop Diagrams (CLD) that establish the qualitative relationships and cycles between variables that later are transformed into equations in the Stock and Flow Diagram (Sterman, 2000).
CLDs have the form of an oriented graph and are designed to explain the causal structures within the system. The arrows represent the link between different

variables. The influences among the variables can be positive (denoted by "+") or negative (denoted by "-") (Castelblanco, Guevara and Mendez-Gonzalez, 2022b). CLDs are made of two kinds of loops: reinforcing ones that strengthen a behaviour, and balancing ones, which on the contrary, indicates that the loop counteracts the effect of a change (Armenia, Tsaples and Franco, 2022)

Stock and Flow diagrams have four main components: stocks, flows, auxiliary variables, and connectors (Zenezini and De Marco, 2020). Stock represents cumulation, and these are modelled quantitatively as integrals of the differences between the two types of flows, namely, inflows and outflows. Auxiliary variables may be constant over time or may be changeable. The last component of the Stock and Flow Diagram are connectors which represent the relationships between all the other components, which could influence either positively or negatively the variable (Cagliano et al., 2015).

The CLD (Figure 1) explains the causal structures within the system to estimate the long-term financial effects of PPPs on the government and society. The casual loop shows two reinforcing loops (R1 and R2) and one balancing loop (B1). The reinforcing loop (R1) focuses on the pipeline of projects that constituted the PFI and PF2 programs. R1 shows that as more projects are initiated, the higher the number of projects in construction, and after the construction period ends, those projects become Operating PFI, and this results in more Transferred PFI to the public sector after the time of the operation period has concluded (Pagoni and Patroklos, 2019). The increase in PFI Supply also increases the number of projects that may be procured a second time resulting in a higher Number of PFI initiated.

The second reinforcing loop (R2) shows that that relations of PFI initiated and Capital Value. If the PFI initiated are increasing this leads to an increase in the Capital Value invested by the private sector. This will result in restricting the Average IRR, limiting the Interest Rate Gap, and, consequently, stimulating an increase in the Number of PFI initiated.

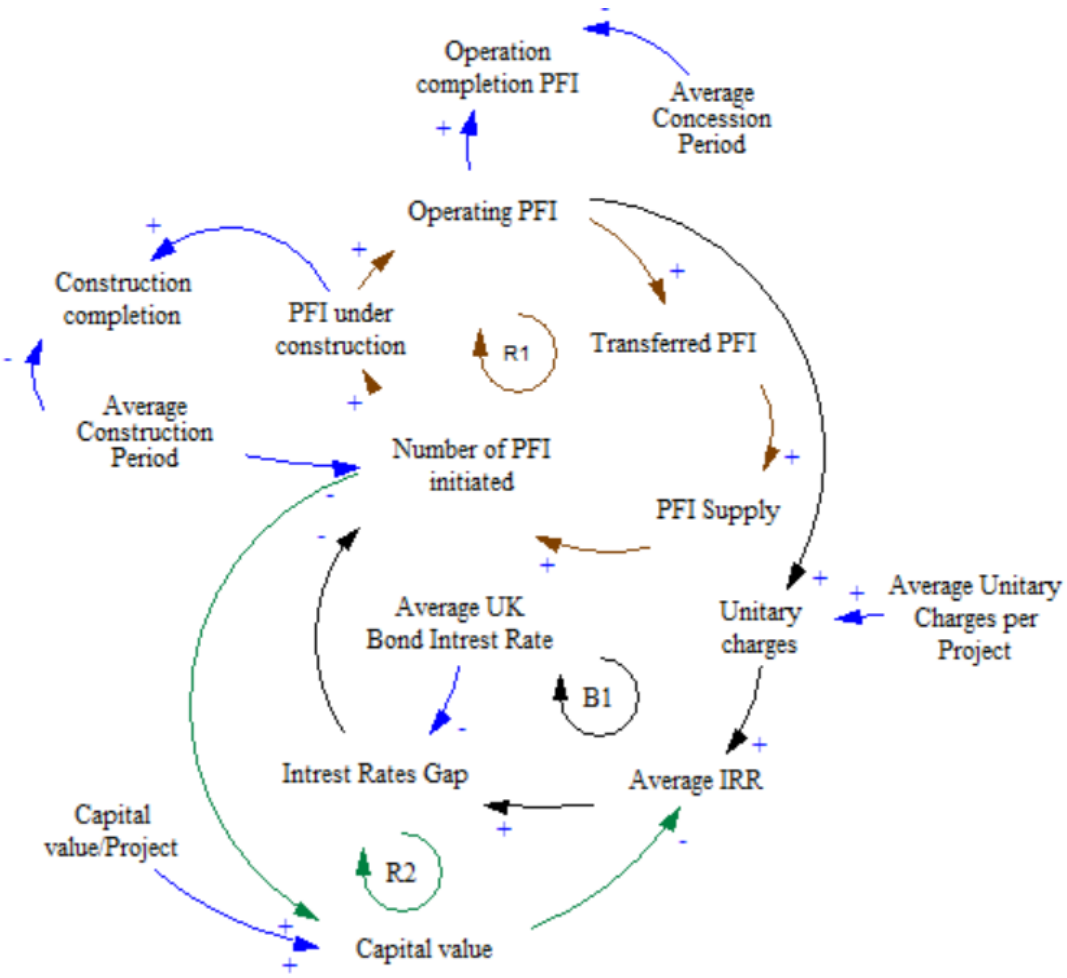

Figure 1 Casual Loop Diagram

Simultaneously, the balancing loop (B1) is focused on restricting the number of PFI initiated. The more operating projects, the higher Unitary Charges paid by the public sector to the concessionaires as these payments are made during the operation period. Moreover, the increase on Unitary Charges will lead to a higher Average IRR, which increases the Interest Rates Gap when compared with the Average UK Bond Interest Rate. Finally, the higher the Interest Rates Gap will result in a lower number of PFI initiated due to the erosion in the social legitimacy and, consequently, political opposition. This simultaneously will lead to lower number of PFI under construction and in result to lower number of Operating PFI.

Based on the CLD, the Stock and Flow Diagram was developed (Figure 2). The model created for this paper has set a unit of time as a "year" and the time starts in 1993 as it is the date of the first project. The model incorporates three stocks: PFI under construction, Operating PFI, and Transferred PFI. PFI under construction decrease by the Construction completion, which is subject to the Average construction period. In the case of Operating PFI, this stock increases with Construction completion. The last stock, Transferred PFI increases by the Operation completion PFI. All these stocks are leading to the variable PFI Supply, which is the total number of projects regardless of the stage (PFI under construction + Operating PFI + Transferred PFI). The Average IRR is calculated depending on the Capital Value and Unitary Charges indicating the profitability for the private investor. Finally, the Interest Rates Gap shows the

difference between the Average IRR and the Average UK Bond Interest. A positive gap represents a higher detrimental effect on public finance.
Table 1 lists all the exogenous parameters used for Stock and Flow diagram modelling. The quantitative outcomes of the SD model were validated with the information retrieved from the UK Home Office.

Exogenous parameters

Table 1: List of exogenous parameters

Parameter	Value	Units
Capital value/Project	81.1	mln £
Average construction period	3	years
Average concession period	28	years

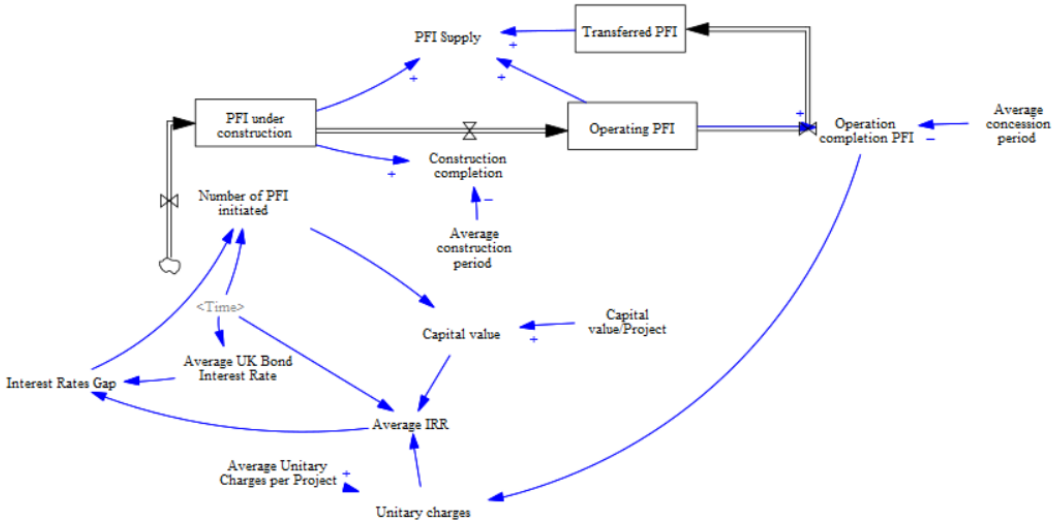

Figure 2 Stock and Flow Diagram

FINDINGS & DISCUSSION

The SD model simulation was employed to unravel some relevant issues of the PFI & PF2 programs that resulted in the discontinuation of these PPP programs. Overall, three major weaknesses emerged from the analysis, namely, higher costs than traditional procurement, lack of transparency, and cost overruns.
The first pitfall identified from the SD model is the higher costs of PFI/PF2 projects compared to traditional public sector procurement, leading to higher costs for taxpayers. To quantify the cost for the public sector derived from the PFI/PF2 programs, Figure 3 presents the total capital value and unitary charges corresponding to the 704 projects developed since the beginning of the PFI program in 1993 (corresponding to year 0 in the model) until 2043 (year 50). The capital value corresponds to the sum of equity and private debt required for the financial close, which usually is the amount required for the capital expenditures during the construction phase. Conversely, the unitary charges are the availability payments from the public sector to be paid on a yearly basis during the operation period. Figure 3 shows the difference in the order of magnitude between the private investment (capital value) and the public payments (unitary charges). This significant difference between them reflects the impact of guaranteeing private profitability in the long term. Consequently, the longer concession period of PFI projects (28 years on average)

could have negative financial implications for the public sector and taxpayers that have to pay more respecting public financing. It could also lead to unfavourable circumstances for the facilities once the PPP agreement concludes and ownership is transferred (Khanzadi, Nasirzadeh and Alipour, 2012; Castelblanco, Guevara and Mendez-Gonzalez, 2022a).

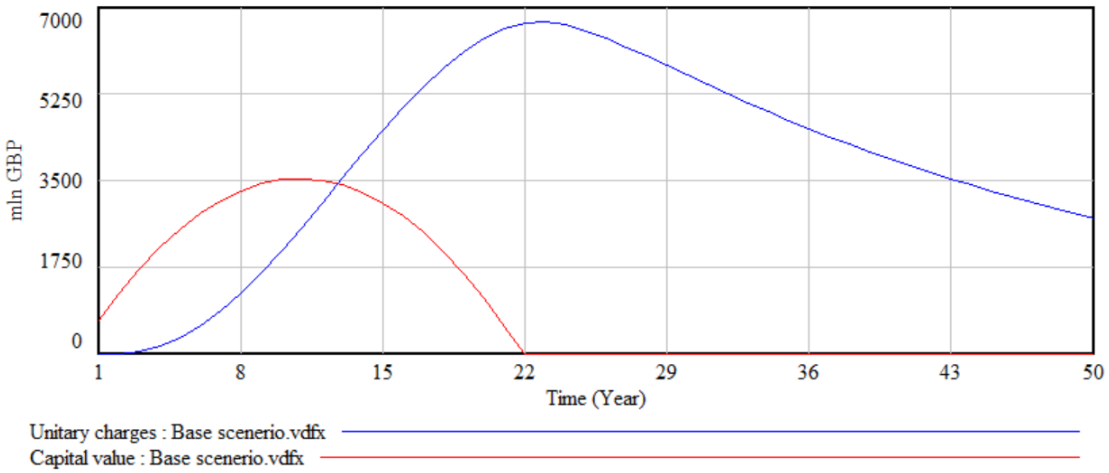

Figure 3 Unitary charges vs. Capital Value

To quantify the profitability, the SD model calculates the Average IRR of the 704 projects, which is 16,3% when all the payments until 2052 are taken into account (Figure 4). In comparison, the average interest rate of the UK-10-year Government Bond since the beginning of the PFI program is 5,2% ("IEO Annu. Rep.," 2009). Consequently, there is a huge gap between the IRR for the private sector, based on the initial investment of equity and private debt, and the interest rate for public debt that is employed for financing traditional procurement projects. Moreover, the detrimental effect of this gap is even bigger for the public sector considering the long-term concession periods. In general, high IRR for long-term concession periods results in much higher Unitary Charges and what goes after also higher tax payments from people in comparison with short-term project deliveries such as Design-Build. Moreover, a high debt leverage in the PFI program also implied reduced flexibility in funding sources, as the repayment of debt is mandatory regardless of the revenue generated (Santandrea, Bailey and Giorgino, 2016; Marcellino, Castelblanco and De Marco, 2022b) contrasting with equity investment that does not have such constraints.

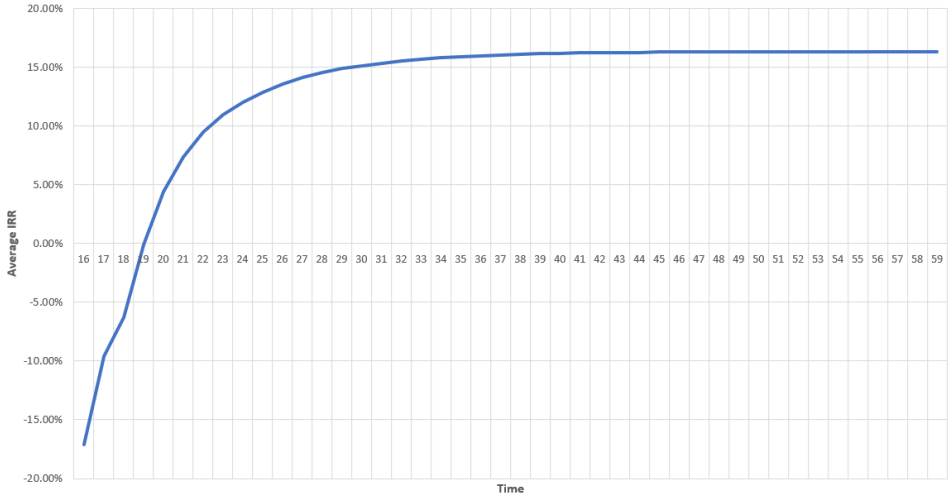

Figure 4 Average IRR

The second weakness of this PFI/PF2 program identified in this research is the cost and time overruns. Initially, when PFI was first introduced, business cases assumed that public sector projects would experience a cost overrun of 12.5% or more (D. Gaffney, et al., 1999). However, the cost and time overruns in the PFI program ranged between 22% and 35% by the early 2000s ("IEO Annu. Rep.," 2009) contrasting with the range between 2% and 24 % in conventional procurement (Leahy, 2005).

The model simulation allows for assessing the impact of cost overruns. Figure 5 compares the Unitary Charges in two scenarios: the first one is the baseline scenario (without any cost overrun), and the other is the cost overrun scenario which considers 24% of average cost overrun according to previous research on the performance of PFI projects (Leahy, 2005). Moreover, cost overruns, ultimately, leads to higher Unitary Charges to compensate the concessionaire, which impact significantly the public budget and may result in rejection of potential new projects because the is required increasing budget for the ongoing PFI projects than initially estimated. Overall, recurrent cost overruns may even endanger the Value for Money estimations. Therefore, a project that reached Value for Money valuation for being conducted as a PFI project instead of alternative project deliveries may not accomplish these estimations because of the renegotiations during the long life-cycle. As a result, the public sector must use increasing resources from taxpayers than expected. The significance for taxpayers is reflected in the £10.7 billion paid between 2010 and 2015 as Unitary Charges only for hospitals and other healthcare facilities built under the Private Finance Initiative (Centre for Health and Public Interest, 2017).

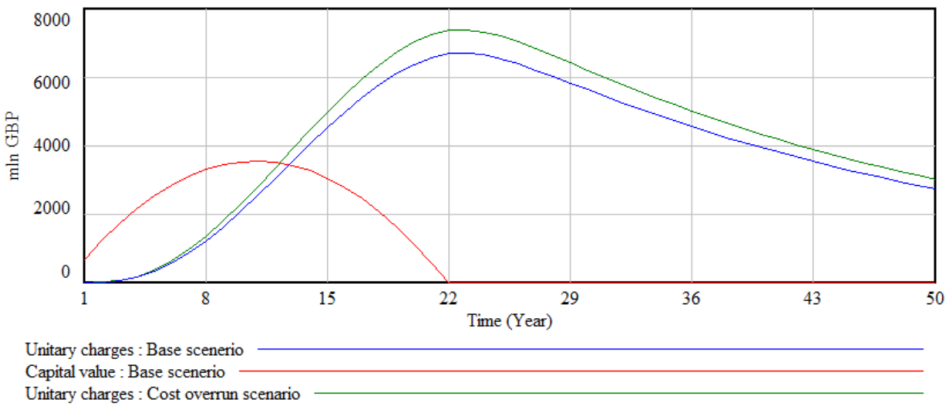

Figure 5 Unitary charges vs Capital Value under Cost Overrun

One meaningful example of projects affected by time and cost overruns is the London Underground Jubilee Line extension, which was delivered more than two years late and £1,4 billion over budget (Hodge and Greve, 2010). Another eloquent example of projects with significant costs overruns is the Crown Prosecution Service signed in 2001 for 10 years, but the estimated outturn cost was £408 million, a 70% increase due to the “improved service levels and extended to more staff" (Whitfield, 2017).
The government can also be locked into paying for services, even if it no longer requires them, as demonstrated by the Liverpool City Council project. The council is paying around £4 million each year for Parklands High School which is now empty. Between 2017-18 with the contract ending in 2027-28, it will pay an estimated £47 million, which includes interest, debt, and facilities management payments. The school cost an estimated £24 million to build (NAO, 2018). Even though there are no more PFI/PF2 projects in the UK, future charges lasting until the 2040s amount to £199 billion (Foreman-Peck, 2021).
The government is also incurs losses when it abandons projects. An example of this misbehaviour is the 2009 "Defence Training Rationalisation project" for the Ministry of Defence, which had to be cancelled since the bidder was unable to deliver an affordable proposal. The cost of cancellation of this project was £32.4 million (Whitfield, 2017).
Additionally, a significant time overrun can also lead to an overrun in cost. Time overruns may affect indirect costs during the construction phase, long-term costs during the operation phase, and financial costs. The "Northern Ireland Vehicle Licensing Agency" is an example of this misbehaviour as it was delivered six years late, and the final cost increased by £300 million (Whittfield, 2003).

The third weakness of the PFI/PF2 program is the lack of transparency in the PFI/PF2 programs. During the data collection for building the model, it was found that the public information available mainly shows information based on the business case rather than presenting updates of the current status of the projects and the potential time and cost deviations and renegotiations. Moreover, this kind of information is even scarcer when the financial data is inquired. Overall, the only public information available is focused on presenting the planned capital value, unitary charges, and some basic information such as the date of the first operation and the duration of the contract. The lack of transparency regarding the real financial information impedes a proper public accountability on the projects, resulting in concerns about the potential for private sector companies to take advantage of their position and information asymmetry issues.

In summary, the three weaknesses of the PFI/PF2 programs shown in this research eroded the social legitimacy of the program, resulting in increased political opposition seeking support from voters.

CONCLUSIONS

This paper contributes to the growing body of literature on PPP programs by providing a comprehensive analysis of the long-term social and financial implications of one of the biggest PPP programs worldwide, namely the PFI and PF2 programs in the UK including more than 700 PPP projects. Through the use of SD, this research identified key drivers that shape the interaction between PPP development, societal concerns, public policy, and financial constraints.

The analysis of the PFI and PF2 programs highlights key weaknesses that have led to their eventual closure. Firstly, the high costs of these projects, coupled with the high profitability of private investments in the long-term, has led to concerns about the value for money of these projects. Secondly, the occurrence of recurrent cost and time overruns has further undermined the financial viability of these projects, leading to further scrutiny and criticism. Thirdly, the lack of transparency in PFI and PF2 contracts has raised concerns about the accountability of private sector companies and their ability to take advantage of their position and information asymmetry issues.

The cumulative effect of these weaknesses triggered a loss of social legitimacy for the PFI and PF2 programs, leading to increased political opposition and ultimately, the termination of these programs. This highlights the importance of ensuring that PPP programs are designed and implemented in a way that maximizes their social and economic benefits while minimizing their costs and risks.

Moving forward, future research should analyse comparatively the projects among the multiple infrastructure types and specific public owners at a national, regional, and local levels. Moreover, future research should explore alternative models for financing and delivering public infrastructure that may serve to the UK Home Office to build a sound program that still lacking nowadays. These models may offer a more sustainable and equitable approach to delivering public goods and services, while addressing some of the key challenges associated with traditional PPP programs.

Overall, this research underscores the need for a more holistic and collaborative approach to public infrastructure development, one that prioritizes transparency, accountability, and stakeholder engagement to prevent excessive financial costs and renegotiations.

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