Contracting Out Public Transit Operation Services:
An Incentive Performance-Based Approach

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The literature on public transit services contracting, emphasizes the need of efficient contracting designs to promote parties' interest alignment. There is, however, limited research addressing specific incentive mechanisms. The paper contributes to that literature by developing a performance-based model with an embedded incentive bonus/malus (B/M) mechanism for contracting out transit services. Monte Carlo simulation documents that model's performance appears sensitive to stochastic specification of some of the B/M drivers, and responsive to changes in the contractual performance factors out of the sub-concessionaire's control. Evidence on the operation of a light-rail transit system designed based on a version of the model, document that it may contribute to promote ridership patronage, increase the average ride, and ultimately promote the economic operating efficiency of the system. Some policy implications are drawn, namely in terms of public funds allocative efficiency, and promotion of social welfare in contracting transit services.

Key words: public transportation; privatization; performance-based contracting; bonus/malus mechanism
JEL Codes: H40; L24; L33

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1. Introduction

More and more public transportation agencies and authorities around the world are externalizing the provision of infrastructure development and the operation of their transit systems, raising the question: why are they doing this?

It is widely acknowledged that for decades, public transit agencies around the world have been striving to deliver good quality and socially fairly-priced mobility services, while aiming at minimizing the environmental negative externalities, namely, those associated with traffic congestion and safety, and air pollution. However, extant literature has documented that the provision of public transit services often has not successfully achieved the economic, social and welfare goals underlying governmental contracting out for infrastructure development and operation (e.g., Xue *et al*., 2017; Pereira *et al*., 2017; Desaulniers and Hickman, 2007; Nash, 2005; Teal, 1985).

It appears to be a well-established global trend that financially strained and budgetarily constrained public transit service providers have been facing increasing difficulties in investing in infrastructure and equipment, in improving operating efficiency, recovering ridership, and balancing the economics of the operation (e.g., National Academies of Sciences, Engineering, and Medicine, 2014). Financial and budgetary constraints at the government level may have also limited the governmental sponsorship of new transit infrastructure development projects and the revamping of the operation of existing ones.

The question of whether or not the ownership of economically productive assets matters, in terms of relative economic efficiency, has been a topic of extensive debate among academics, policymakers, regulators and practitioners alike. A non-negligible body of privatization literature provides theoretical arguments and documents empirical regularities

suggesting that the private sector dominates governmental management in terms of the relative economic efficiency of productive assets (e.g., Iwasaki *et al.*, 2018; Boycko *et al.*, 1996; Vickers and Yarrow 1991).[1]

Such economic gains, arguably associated with the externalization of management activities to the private sector, are also predicted to be important drivers of the privatization of the operation of public transportation systems, through competitive performance-based contracting arrangements (e.g., Merkert *et al.*, 2018; Macário *et al.*, 2015; Amaral, 2008; Rodrigues and Contreras-Montoya, 2005).[2]

During the last decades, central and local governments alike have attempted to balance the economics of the operation of transit systems, striving to maintain low transit fares and profitable operations, while reducing operating costs, maintaining the level of service quality, and improving ridership (e.g., Xue *et al.*, 2017; Teal, 1985).

However, with the increase in households' disposable income and the rise in motorization rates, mass transit services have experienced a steady decline in ridership over time. This environment, characterized by depressed demand, operating deficits, debt overhang, and even financial distress, has carried non-negligible implications for regulated transit operators, namely, in terms of their ability to attract investment capital.

Nonetheless, as it is largely recognized, the operation of public transit systems in many metropolitan areas around the world has been associated with technical and allocative inefficiencies, which, despite non-negligible governmental subsidization, has placed the

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[1] See, e.g., Bachiller (2017), Boubakri *et al.* (2013), Omran (2009, 2004) for a contrasting viewpoint.
[2] Hereafter, we use interchangeably 'competitive contracting', 'competitive tendering', 'performance-based contracting', 'competitive bidding' and 'incentive contracting'.

financial and budgetary condition of many transit system operators under significant distress (e.g., Xue *et al*., 2017; Winston, 2000).[3]

Financial, budgetary constraints, and efficiency concerns have caught the attention of public policymakers to consider alternative procurement contracting arrangements for the development of infrastructure, and the delivery of public services. Namely, to procure the provision of infrastructure development, operation and financing of transit services from the private sector. These developments have promoted financial aid from state and local governments and fostered the level and amount of public mass transit competitive contracting, increasing the involvement of the private sector in the provision of public transit operation services (e.g., Buso *et al*., 2017; Levin and Tadelis, 2010; Maskin and Tirole, 2008; Annez, 2006; Transportation Research Board and National Research Council, 2001).

Since the 1970s and 1980s, a dynamic stream of innovative financial instruments and customized structuring designs have significantly enlarged the supply of corporate financing arrangements in various forms of asset-backed structured financing, namely, limited recourse project financing, public-private partnerships (PPPs, hereafter), asset securitization, and structured leasing (e.g., Pinto and Santos, 2020; Annez, 2006; Duffie and Rahi, 1995; Finnerty, 1988).[4]

Increasingly, more and more mass transit agencies and authorities worldwide have been sponsoring the privatization of the operation of public transport systems through competitive

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[3] According to the Transportation Research Board and National Research Council (2001, pp. 138), in the United States «a decline in the demand for transit services began in the 1920s, accelerating after World War II. Private operators, already unable to attract investment capital in a regulated environment with falling demand, found it increasingly difficult to cover operating costs. By the 1950s, hundreds of systems were failing or in severe financial distress».

[4] For further details see, e.g., Pinto (2013) and references cited therein. Structured finance encompasses all financial arrangements helping to efficiently (re)finance a specified pool of assets beyond the scope of on-balance sheet financing. Thus, the presence of a separate vehicle company (SPV or SPE) from the party or parties sponsoring the transaction is a key feature of such transactions.

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procurement. In Europe, transit privatization initiatives conducted under the contracting out of transit operation services, became more frequent in the early 1980s (e.g., Nash, 2005).[5]

However, there is a relatively scant literature on the design and implementation of real-world incentive contracting arrangements, that could promote the alignment of the interests of the various parties involved in such contracts.

In this paper, we aim at filing this gap, contributing to the literature by presenting an incentive performance-based bonus / malus (B/M) model. Because the proprietary information, to both a concessionaire and a subconcessionaire, required for conducting a clinical research was unavailable, we illustrate the implications of our approach, with a hypothetical light-rail project. Because a closed-form tractable solution for the model is unfeasible, we use Monte Carlo numerical methods to approximate a solution incorporating stochastic variability into a deterministic base-case. Simulation results show that the model's performance appears sensitive to variability of the B/M drivers, and responsive to changes in the contractual performance factors out of the sub-concessionaire's control.

In addition, we provide evidence of some performance realizations of a contract awarded in 2010 by MdP after a competitive international tender, which was structured and incorporated some features of our B/M model. Empirical findings from MdP's showcase document that the implementation of a performance-based contract with an embedded incentive B/M mechanism promoted the overall economic operating efficiency of the system.

The remainder of this study is organized as follows: Section 2 discusses the theoretical and empirical background. The next section describes our research design, methodological approach, and model specification. Section four presents the results of a Monte Carlo

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[5] For more details, please refer to Transportation Research Board and National Research Council (2001, pp. 138-147).

simulation analysis for our B/M model, and documents some performance metrics of Metro do Porto's (MdP) 2010-2014 operation and maintenance contract. The final section provides a summary and offers concluding remarks.

2. Theoretical and Empirical Background

2.1. The ownership of business activities

Prior academic and practitioners' work on the economic consequences of the privatization of state-owned assets documents abundant evidence on economic, financial, and operating performance gains, following such ownership divestitures. Therefore, if the operation of government-owned assets is more efficient under private management, it can be expected that the performance improvements associated with privatization arrangements will yield allocative and productive efficiency gains.

Extant privatization literature provides abundant evidence consistent with the hypothesis that the privatization of business activities generates performance improvements that translate into significant gains, namely, in terms of profitability, operating efficiency, investment and production (e.g., Okten and Arin, 2006; Sheshinski and López-Calva, 2003; Dewenter and Malatesta, 2001; Megginson and Netter, 2001; Shirley and Walsh, 2000; D'Souza and Megginson, 1999; Boubakri and Cosset, 1998; Megginson *et al.*, 1994).

Extant literature is consistent with the argument that performance-based competitive contracting of the operation of public transit systems may be instrumental «to combine the efforts of public and private institutions related to public transport for the purpose of coordinating services, networks, and fares so as to offer consumers a higher-capacity, higher-quality service, with the aim of promoting public transport use and shifting demand away from private cars» (García-Ferrer *et al.*, 2006). In the same vein, Hencher and Houghton (2004)

argue that in many countries, there are growing concerns with operating cost efficiencies of bus transit operation services associated with the «mixtures of privatisation, economic deregulation and competitive tendering and finding ways to grow patronage».[6]

The economic gains potentially associated with the privatization of management are also suggested as a determining factor in the strong and growing tendency to privatize the operation of public transit systems through the use of sub-concession public offer mechanisms (e.g., Amaral, 2008; Rodrigues and Contreras-Montoya, 2005). For example, Nash's (2005) examination of privatization phenomena in the transportation sector concludes that «for rail and bus services, franchising of passenger services and outright privatization of freight appear to have achieved both efficiency improvements and improved services».

It is well-known that state sponsorship of the provision of public goods may have been constrained by budgetary and financial restrictions at the government level, and by concerns over the allocative efficiency of public resources. To address these policymaking constraints, the contracting of public-private partnerships (PPPs) started to be extensively used by public administration bodies to procure design-build-finance-operate (DBFO) services, aiming at mitigating and reaping the performance improvements associated with the private delivery of public goods (e.g., Reagan *et al*., 2011; Levin and Tadelis, 2010; Hart, 2003). Under these conditions, there was a significant increase in the volume of infrastructure projects funded in structured finance worldwide markets, in the form of either non-recourse project finance (PF, hereafter), public-private partnership (PPP, hereafter), or structured leasing transactions.[7]

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[6] See Sarmento and Renneboog (2016) for an overview of different public sector procurement systems, and features of public/private sectors responsibility sharing under PPP arrangements.

[7] In a typical PPP, the governmental party contracts a private partner to carry out the development, construction, financing and operation of a project, and is compensated by a "combination of government payments and user fees" (Maskin and Tirole 2008). According to Pinto and Pacheco (2014), structured leases, typically used to fund large assets, are versatile instruments that enable the lessee to position the deal in an optimal manner in relation to cash flow structure, its sustainability over time and the distribution of tax benefits.

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According to, for example, Kwak *et al*. (2009), well-designed and managed PPPs «can provide a number of benefits to the public sector such as: alleviating the financial burden on the public sector due to rising infrastructure development costs; allowing risks to be transferred from the public to the private sector; and increasing the "value for money" spent on infrastructure services by providing more efficient, lower cost, and reliable services». These PPPs' attributes granted them widespread notoriety, to a large extent, based on their potential advantages, namely, in terms of «…alleviating the financial burden on the public sector», and in providing «efficiency incentives from private sector management into network industries» (ITF, 2017; Kwak *et al*., 2009).[8] However, efficiency gains of DBFO arrangements associated with bundling construction and operation services in a single contract may, as argued by Maskin and Tirole (2008), be elusive because «the best developer might not also be the best operator». Furthermore, it may encourage choices that reduce future costs at the expense of service quality» (see also Hart, 2003).

Empirically, Albalate *et al*. (2010) analyze in a PPP framework, the challenges and opportunities of partial privatization of the public bus service provision in the metropolitan area of Barcelona, arguing that sub-concessions to private operators may "stimulate improved performance among public managers".

Findings from another study on the operating performance of Spanish bus companies indicate that «public firms are more intensive in the use of labor, but workers' productivity is lower compared to those in private firms. However, wages are 18 percent higher in public firms. These facts indicate the presence of allocative X-inefficiency in public firms, which is

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[8] As posited in Maskin and Tirole (2008, pp. 413) «the marked increase in PPP contracts worldwide is often attributed less to the intrinsic qualities of such contracts than to governments' attempts to evade budget constraints by taking liabilities off the balance sheet». See also Vaslavskiy and Vaslavskaya (2019).

observed in the different performance of both groups: average costs are 42 percent higher in public than in private firms» (De Rus & Nombela, 1997).

Sarriera *et al.* (2018) examine the impact (lack) of productivity growth, union bargaining power, and contracting out on cost escalation, based on a sample of the 415-bus U.S. transit agency for the 1997–2014 period. Authors find that, in recent decades, unit costs per vehicle mile of bus operators have increased considerably above the inflation rate in recent decades.

2.2. Transit Services Contracting Out

A non-negligible number of public transit agencies across the world experienced significant cost increases, economic deficits, and liquidity shortfalls during the last decades. Furthermore, whenever promoting the efficiency of public transit services, delivery is a major public policymaking objective, performance-based procurement, e.g., in the form of competitive tendering should be a serious contender to be considered (e.g., Hensher and Wallis, 2005).

A panel data analysis, conducted by Roy and Yvrande-Billon (2007) of a sample of 135 different French urban transport networks over the period 1995-2002, documents that the technical efficiency of public mass transit provision may be affected by car ownership and the passenger-based incentives included in the contract design. In the U.S., according to Love and Cox (1993), «transit operating costs per vehicle mile increased 418 percent from 1970 to 1990 twice the rate of inflation and two-and-a-half times the cost of a similar service in the private bus industry».

In this framework, mass transit public agencies may have been led to switch from directly operating their transit networks to contracting out their service operations with private operators (e.g., Teal, 1991; Reich and Davis, 2011; Nicosia, 2001).[9]

Competitive contracting has drawn significant attention from, among others, academic, policymaking, regulatory, and industry communities. It is relatively consensual among those communities that the competitive delivery of a «good quality, integrated and continually improving transit service that is available to all for a fair price, with return to operators that gives value for money under a regime of continuity», is a major objective in procuring the provision of public transit services (Hensher and Stanley, 2008).

According to this literature, performance-based contracting of public transit services, namely through competitive tendering, appears to be an appropriate vehicle «to combine the efforts of public and private institutions related to public transport for the purpose of coordinating services, networks, and fares so as to offer consumers at higher-capacity, higher-quality service, with the aim of promoting public transport use and shifting demand away from private cars» (García-Ferrer et al., 2006).[10]

Sheshinski and López-Calva (2003) point out that theoretically, «it is known that incentive and contracting problems create inefficiencies due to public ownership». One of them is the equitability of the reward systems stipulated in performance-based contracting arrangements. Such provisions should not be sensitive, either positively or negatively, to factors exogenous to the transit operator´s contractual activity. For example, changes in

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[9] As suggested by Reich and Davis (2011), a «method that has long been credited with increasing transit efficiency and reducing operating costs is contracting with the private sector for the provision of transit service».
[10] According to Hensher and Stanley (2008), performance-based contracting «combines payment for delivering a minimum level of service (…) plus an incentive that rewards operators for patronage increases» above the minimum level of service in terms of both service and patronage. See Sheng and Meng (2020) for a recent comprehensive review of the literature on contracting out in transit service markets.

regulated transportation fares, either inducing the increase or the decrease in ridership, should not be reflected in the contractual performance measures of the sub-concessionaire (e.g., Hensher and Stanley, 2003).

As numerous public transit system fares are governmentally regulated, and concessionaires have contractual property rights over farebox collection, under a public mass transit gross-cost contract, sub-concessionaires' contracts may require them to fulfill some stewardship duties, such as fare collection monitoring and fare evasion control, although they do not have incentives to ensure farebox revenue collection.

According to Weitzman (1980), an incentive contract is «a linear payment schedule where the buyer pays a fixed fee plus some proportion of project cost». This theoretical approach to efficient contracting, based on a tradeoff between risk-sharing and incentives, may be suitable for practical implementation.

Transit service contracts may include monetary incentives based upon a specific performance metric to motivate contractors to outperform services beyond the goals contractually stipulated. Similarly, contracts may also involve monetary penalties to be enforced whenever non-compliance with contractual service goals occurs (e.g., Hillman and Feigenbaum, 2020; Vigren and Pyddoke, 2020).

Performance-based contracts typically include monetary penalties to be enforced whenever contractual service goals, such as ridership, service standards in terms of, e.g., quality and frequency, and level of customer satisfaction, are not met, a malus (e.g., Hillman and Feigenbaum, 2020).

There is broad agreement among academics, policymakers, regulators and practitioners that performance-based competitive contracting of «good quality, integrated and

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continually improving transit service that is available to all for a fair price, with return to operators that gives value for money under a regime of continuity», is a key goal in contracting public transit services (Hensher and Stanley, 2008). In this framework, the rationale for stipulating the sub-concessionaire's contractual incentives, should reflect the concessionaire's expectations on cost efficiency gains, operating improvements and patronage increases.

Prior work suggests that performance-based contracting of transit service provision is consistent, under specific budgetary, regulatory and geographical conditions, with the principle of social surplus maximization. However, competitive tendering may be less effective (e.g., Hensher and Stanley, 2008).

Literature on incentives in procurement contracting at large, and in transit services competitive tendering, report, among the more ubiquitous contractual arrangements: (a) the cost-plus contract; (b) the gross cost contract; and (c) the gross cost contract with incentives (see, e.g., ITDP, 2017; Glachant *et al*., 2012; Laffont and Tirole, 1993, p. 12-13).

In a cost-plus contract, the sub-concessionaire receives compensation for all the contractually stipulated expenses, as well as additional payment to allow for a profit. The more conspicuous features in a cost-plus contracting model, include: (*i*) the assignment of farebox revenue property rights to the concessionaire; (*ii*) the sub-concessionaire being reimbursed for operating costs, which may include a management fee; (*iii*) no commercial or operational risk-sharing; and (*iv*) the only incentive for cost control is the risk of contract non-renewal.[11]

A gross cost type of contract is awarded to the lowest gross cost bidder. Property rights of farebox revenue are assigned to the concessionaire. The sub-concessionaire is compensated with a specified monetary sum, submitted to competition, for providing the specified operation

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[11] Cost-reimbursement contracts contrast with fixed-price contract, in which contractors are paid a negotiated monetary amount regardless of the expenses incurred in the provision of the services outlined in the contract.

services stipulated in the contract, which typically also includes penalties for non-compliance. The sub-concessionaire is not exposed to commercial risk but is exposed to operational risk.

In a 'gross cost with incentives' contracting arrangement, the farebox revenue is the property of the concessionaire. The sub-concessionaire is remunerated based on a demand-based criterion, for example ridership measured in passenger-kilometer, which is submitted to competition. It constitutes an incentive for a sub-concessionaire to increase their remuneration, promoting actions to foster demand. In this contracting model, the sub-concessionaire is exposed to operational risk, and partly to demand risk, through an incentive mechanism, such as a bonus/malus mechanism, which constitutes an incentive for the sub-concessionaire to engage in actions to promote ridership and increase their monetary compensation.[12]

Our paper develops a version of a 'gross cost with incentives' contracting model, which served as the basis for an international tender offer to operate and maintain MdP's light-rail system, implanted in Porto metropolitan area, Portugal.

3. Research Design, Methodological Considerations and Model Specification

The set of assumptions underlying the specification of our 'gross cost with incentives' contracting model include a 7-year contract term, transit fares set at the regulatory level, farebox collection under the concessionaire's responsibility, and a transit demand function estimated under the concessionaire's jurisdiction.

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[12] It is only exposed to the quantity component of the commercial risk because, in addition to transit fares being governmentally regulated, farebox revenue is collected by the concessionaire.

Transit demand functions have been estimated under different econometric specifications. Our modeling setup is methodologically anchored in log-log regression econometric approach to estimate a transit demand function, the 'reference demand'.

Several methodological arguments endorse the use of isoelastic demand functions for estimating ridership of public transit systems. One argument, favoring the use of this non-linear regression specification, is anchored in the particularly interesting feature, of the explanatory variable's coefficient estimators measuring the constant partial elasticities for the dependent variable (e.g., Allen *et al*., 2005; Weber and Hawkins, 1971).[13]

For example, García-Ferrer et al. (2006), estimated the elasticity of demand for public passenger transport in the transport system of the metropolitan area of Madrid, adopt a different model due to using use demand monthly data, which exhibit significant levels of non-stationary seasonality.

A second argument builds on the 'reasonableness' of the assumption of constant partial elasticities. There is abundant empirical evidence supporting the hypothesis that the elasticity of demand for public transit systems is constant in relation to its explanatory variables over short / medium-term time horizons. Nijkamp and Pepping (1998) argue that the likelihood of such demand elasticity reflecting changes in the conditions of provision of the transport service is higher for long-term horizons. Therefore, the authors conclude that it is expected that long-term elasticities are higher than short-term. This conclusion can be interpreted as providing support for the argument that elasticity of demand for public transit systems is

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[13] See García-Ferrer *et al*. (2006) for an estimation of demand elasticity for the multi-modal transit system of the metropolitan area of Madrid. Their regression specification is particularly relevant in the context of an intermodal public transit system because it documents that the hypothesis that modal demand-price cross-elasticity may be stationary, cannot be rejected.

stationary over medium-term time horizons (5 to 10 years).[14] According to Hensher and

Young (1991), the Research Transport Center of the Bureau of Transport and

Communications Economics, Canberra, Australia, recommends a five-year fuel price

elasticity in the road passenger vehicle segment (see also Graham and Glaister, 2002;

Goodwin, 1992; Hensher and Young, 1991). In the same sense, Nijkamp & Pepping (1998)

analyze «(...) own-price regular elasticities, where the dependent variable is travel volume,

and the independent variable is travel cost».[15]

The specification of a regression model should be adequately grounded on the relevant

theoretical and empirical literature. The regressors most frequently used in econometric

models for estimating transit demand include, among others, disposable income, fuel prices,

prices of other transport modes, and variables associated with demography, such as the

resident population and the rate of activity (e.g., Holmgren 2007; Garcia-Ferrer et al., 2006).

Our Bonus/Malus (B/M) contracting model is based on a set of assumptions that the

concessionaire adopts, either directly or through outsourcing with professional consultancy

services : (*i*) develops a standard costing estimation on both fixed and variable costs of the

operation of the transit system, to ensure that the sub-concessionaire's compensation is based

on efficient costing benchmarks;[16] (*ii*) develops construction a long-range (20 to 30 years),

including a demand forecast under previously validated methodology and assumptions; (*iii*)

defines a mandatory minimum system operation schedule (MOS) for the transit network on

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[14] It is worth noting that the contractual term may also be related to demand elasticity. Under a bonus/malus incentive contract, the mechanisms a sub-concessionaire may adopt to increase patronage to maximize bonus, requires a minimum period for producing output effects and for internalizing the associated costs.
[15] Oum *et al*.'s (1992) finding of strong evidence indicating that the demand for individual and collective (urban) passenger transport is inelastic is consistent with our conjecture that the elasticity of transit demand is relatively stable in short to medium time horizons.
[16] Cost benchmarks should allow the 'vehicle_Km' standard cost to be estimated and decomposed into 'vehicle_Km fixed standard cost' (k_F), and 'vehicle_Km variable standard cost' (k_V), which are the main elements of the sub-concessionaire's remuneration contractual arrangement.

its current configuration, based on the 'reference demand' to the term of the contract; and (*iv*) stipulates the maximum profit margin, *m*, allowed for the operator; and (*v*) defines the upper (UL) and lower limits (LL) of a demand band.[17]

To estimate the 'reference demand' (*RD*), we specify the isoelastic demand function:

$$Y = aX^bZ^c.^{18} \tag{1}$$

where *Y* denotes *RD*; *X*, the ratio of the individual average monthly out of the pocket expenses with individual private transportation (*EIT*), including fuel, parking, and freeway tolls, to the average monthly out of the pocket expenses with public transportation (*EPT*), the average cost of a non-subsidized monthly season ticket; *Z*, is the active population in the geographical area of influence of the transit system; *a*, is the independent term of regression equation; *b*, is the partial constant elasticity of *Y* on *X*; and *c*, is the partial constant elasticity of *Y* on *Z*.[19]

The sub-concessionaire's compensation scheme has three components. The first, R_F, covers the operator's fixed costs incurred in fulfilling their contractual obligations computed:

$$R_F = \left[(k_F)(1+m)\right]V_{km} \tag{2}$$

where k_F denotes 'vehicle_Km fixed cost', *m* denotes a percentage profit margin allowance, and V_{km} denotes the annualized vehicle_Km production during the time horizon of the contract. The expression $[(k_F)(1+m)]$, which quantifies the 'profit adjusted vehicle_Km fixed cost', is submitted to competitive bidding. The second, R_V, covers the operator's variable costs:

$$R_V = \left[(k_V)(1+m)\right]V_{km} \tag{3}$$

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[17] As the MOS is not subject to competition, the contract should include penalty provisions for non-compliance.
[18] See Appendix A for the derivation of estimators of the forecasted demand function coefficients.
[19] The inclusion of the ITC / PTC ratio as explanatory variable is made under the assumption that both the numerator and denominator vary inelastically to transit demand.

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where k_v denotes the 'vehicle_Km variable cost'. The expression $[(k_V) \times (1+M)]$, profit adjusted vehicle_Km variable cost, is submitted to competitive bidding.[20]

The third component is the B/M annual reward, which embeds a performance-based incentive mechanism, to promote the alignment of concessionaire and subconcessionaire's interests in a contract of public transit operation services.

For fairness and equitability, the B/M model should be insensitive to changes in any contractual performance factor out of the sub-concessionaire's control. To that end, the annual realized demand during the contractual term is yearly adjusted, for the changes on the elasticities computed for each year of the contract term, and the partial constant elasticities implicit in the reference demand function and contractually stipulated.

The annual B/M is a function of the relative performance of the 'adjusted realized demand' in period t, in relation to the 'reference demand' in the same period, both measured in 'Passenger x Km' (Pax_{km}), whenever the first is outside the 'demand band' (DB), defined by its lower (LL) and upper (UL) percentual limits:

Figure 1 – Demand band

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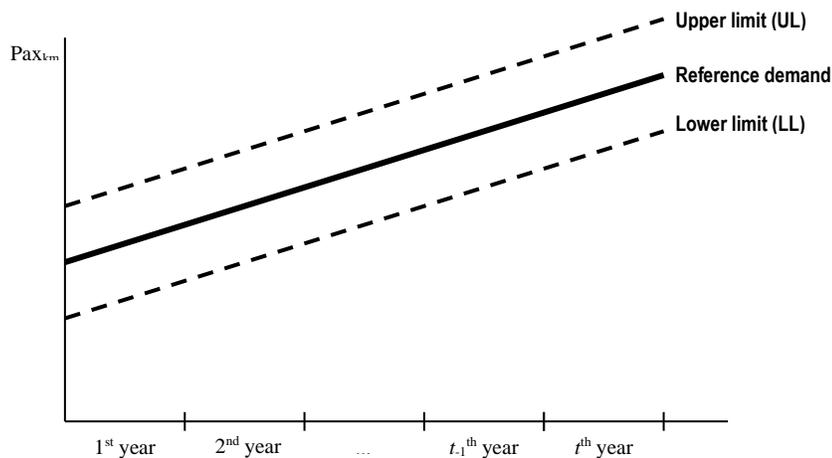
[20] Contractual provisions should enact the annual application of an escalation formula to both k_F and k_V, to adjust for price level changes, and warrant that competitive market conditions are adequately enforced.

Whenever the annual adjusted realized demand falls within the DB, no B/M is due. The annual B/M value is computed using the following formula:

$$B/M_n = \alpha \left[abs \left(\frac{Adjusted\ Realized\ Demand_n - Reference\ Demand_n}{Reference\ Demand_n} \right)^{\beta} \right] \left(R_{F_n} + R_{V_n} \right) \quad (4)$$

where α and β are parameters contractually defined by the concessionaire assuming a law of diminishing marginal returns.[21]

The realized demand is adjusted yearly through the quotient of the independent variable annual elasticities of X and Z to the realized demand dependent variable [see equations (6) and (7)] and the contractually stipulated implicit partial constant elasticities, b and c:

$$Adjusted\ Realized\ Demand_n = Realized\ Demand_n \frac{E_{Y_n\ to\ X_n}}{b} \frac{E_{Y_n\ to\ Z_n}}{c} \quad (5)$$

where $E_{Y_n\ to\ X_n}$ denotes variable Y elasticity to X in year$_n$, $E_{Y_n\ to\ Z_n}$ variable Y elasticity to Z in year$_n$, and b and c are the implicit partial constant elasticities of Y to X and Z, respectively as:

$$E_{Y_n\ to\ X_n} = \frac{\log\left(\frac{Realized\ Demand_n}{10^6}\right) - \log a - c \log Z}{\log X} \quad (6)$$

and

$$E_{Y_n\ to\ Z_n} = \frac{\log\left(\frac{Realized\ Demand_n}{10^6}\right) - \log a - b \log X}{\log Z}. \quad (7)$$

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[21] The upper limit of the bonus mechanism is asymptotically limited by the maximum load factor implied by a maximum 4 per m^2 passenger occupation, assumed as the lowest admissible passenger' s comfort level (e.g., Lomas, 2009).

4. Empirical Analysis

4.1. *Monte Carlo Simulation Analysis*

Because a closed-form solution for the bonus / malus (B/M) model is not analytically tractable, and proprietary information for a clinical study is unavailable, we use Monte Carlo (MC) computational numerical methods to approximate a solution for the model.

With this methodological approach, we aim at describing and understanding the behavior of the B/M model, incorporating stochastic variability into its deterministic base-case.[22] To perform the Monte Carlo simulation analysis, we defined as deterministic, the demand band limits, and equation's A.2 (Appendix A) parameters *a*, *b*, and *c* (see Table 1).

Table 1 – B/M simulation: base case assumptions

The demand band limits were set similarly to MdP's contract. Parameters *a*, *b* and *c* were assumed based on authors' own estimation of equation (1). Subconcessionaire's compensation was estimated based on the value of MdP's 2010-14 contract, adjusted for a 7-year contract term.

Demand band limits	+3% / -3%
Equation's A.2 parameter *a*	2.500
Equation's A.2 parameter *b*	0.950
Equation's A.2 parameter *c*	0.450
Subconcessionaire's compensation ($R_F + R_V$)	285,315,119 (euros)

We, heuristically, assumed and specified as stochastic, Equation's (4) parameters α, β, and the input variables "expenses with individual private transportation" (*EIT*), "expenses with public transportation" (*EPT*), respectively, numerator and denominator of the *X* independent variable, and "realized demand" (see Table 2).

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[22] The Monte Carlo simulation was performed using the software "Oracle Crystal Ball", release 11.1.2.4.900 (64-bits).

Table 2 – B/M simulation: base case stochastic variables specification

Parameters, variable, and probability distributions were heuristically specified by the authors.

Variable / Parameter	Base Case	Probability Distribution	Parameter Estimates
Equation's (4) parameter α	0.15	Uniform	minimum: 0.05; maximum: 0.20
Equation's (4) parameter β	0.95	Uniform	minimum: 0.85; maximum: 1.00
EIT (euros)	825	Lognormal	mean 825; standard deviation 83
EPT (euros)	359	Lognormal	mean 359; standard deviation 36
Realized demand (Pax$_{km}$)	270.10^6	Triangular	minimum: 250.10^6; most likely: 270.10^6; maximum: 300.10^6

We defined as simulation's output variables, the B/M for each year of the contract term. Under those assumptions, specifications, and parameterizations, we performed ten simulation experiments, each one with the number of iterations required to achieve a 95 percent confidence level. Results are summarized in Table 3.[23]

Table 3 – B/M simulation results

Parameters, variable, and probability distributions were heuristically specified by the authors. The simulation was run under a 95 percent confidence level. The number of iterations was the required to reach the specified confidence level. Base case refers to deterministic approach. A B/M is due only when the annual adjusted realized demand falls outside the demand band. The monetization of the B/M was estimated as the product of the B/M in percentage points by the subconcessionaire's annual compensation (= 285,315,119 (euros) / 7-year contract term).

Simulation No.	Iterations	Year 1 Mean	Year 2 Mean	Year 3 Mean	Year 4 Mean	Year 5 Mean	Year 6 Mean	Year 7 Mean	Total
1	10,150	1.316%	0.878%	0.539%	0.185%	-0.055%	-0.371%	-0.654%	1.839%
2	10,350	1.337%	0.893%	0.549%	0.187%	-0.054%	-0.377%	-0.665%	1.870%
3	10,050	1.330%	0.889%	0.546%	0.187%	-0.054%	-0.375%	-0.662%	1.861%
4	10,300	1.340%	0.894%	0.550%	0.189%	-0.054%	-0.374%	-0.663%	1.882%
5	10,550	1.329%	0.887%	0.544%	0.185%	-0.056%	-0.377%	-0.664%	1.848%
6	10,100	1.330%	0.887%	0.545%	0.184%	-0.056%	-0.378%	-0.663%	1.850%
7	10,450	1.334%	0.891%	0.547%	0.187%	-0.055%	-0.376%	-0.664%	1.863%
8	10,650	1.327%	0.886%	0.544%	0.186%	-0.057%	-0.377%	-0.663%	1.847%
9	10,000	1.327%	0.886%	0.545%	0.187%	-0.054%	-0.373%	-0.659%	1.860%
10	10,600	1.340%	0.895%	0.549%	0.189%	-0.057%	-0.378%	-0.667%	1.870%
Grand mean		1.331%	0.889%	0.546%	0.187%	-0.055%	-0.376%	-0.662%	1.859%
Base case		3.030%	2.052%	1.318%	0.726%	0.000%	-0.627%	-1.176%	5.323%
B/M simulation (euros)		542,496	362,217	222,505	76,040	-22,465	-153,093	-269,967	757,731
B/M base case (euros)		1,235,116	836,287	537,225	295,974	0,000	-255,376	-479,439	2,169,786

Simulation results suggest that, over the contract term, the yearly and the accumulated B/M estimated under the deterministic approach tends, as expected, to overestimate the stochastic procedure, 0.760 *versus* 0.266 percent of the subconcessionaire's contractual monetary compensation, respectively. It is worth noting, that both percentages are evidence

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[23] Detailed results are available from the authors upon request, from registered Oracle Crystal Ball (64-bits) licensees.

that model's performance appears sensitive to variability of the B/M drivers, and responsive to changes in the contractual performance factors out of the sub-concessionaire's control.

The grand mean of the ten simulation runs, documents a decreasing trend of the annual B/M percentual score, from a 1.331 percent bonus on the first year of the contract term, to a -0.662 percent malus, on the last year. This may be explained by subconcessionaire's incentives to control costs when approaching the contract maturity.

4.2. Performance Metrics of Metro do Porto's 2010-2014 Operation & Maintenance Contract

MdP, is one of the largest light-rail networks in Europe, in operation since 2002, which received the International Association of Public Transport's (UITP) Light Rail Award / 2008. As of the 2008 year-end, it owned a railroad extension of 59,6 km in the Porto metropolitan area, of which 7.7 km was railway tunnel, and had 70 stations.[24] In 2009, MdP conducted an international tender to operate and maintain its light-rail system. Based exclusively on publicly available information from MdP's website, Table 4 presents some key performance indicators for the 2010-2014 contract term.[25]

Table 4 – Performance during the 2010-14 contract term

	[1] Average 2008-9	2010	2011	2012	2013	2014	[2] Average 2010-14	[3] ([2]/[1])-1
Pax Km (10^3)	260,239	267,064	290,700	282,480	285,591	288,136	282,794	8.7%
Farebox revenue (10^3 €)	29,592	30,649	34,945	37,370	38,879	39,685	36,306	22.7%
Revenue/Pax_km (€ cents)	11.37	11.48	12.02	13.23	13.61	13.77	12.82	12.8%
Operating costs (10^3 euros)	49,573	42,570	42,092	43,217	43,580	43,685	43,029	-13.2%
Op. costs/Pax_km (€ cents)	19.05	15.94	14.48	15.30	15.26	15.16	15.23	-20.1%
Coverage ratio	59.7%	72.0%	83.0%	86.5%	89.2%	90.8%	84.3%	41.2%
Average ride (km)	5.001	4.987	5.216	5.183	5.106	5.062	5.111	2.2%

Source: Primary data drawn from Metro do Porto's 2012 and 2014 annual reports, publicly available at: http://www.metrodoporto.pt/PageGen.aspx?WMCM_PaginaId=17246). Additional information was available at: https://www.metrodoporto.pt/pages/611.
* The 2008-2009 average refers to the two last years of MdP's light-rail operation services, performed under the previous (design-build-operate) bundled contractual arrangement.

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[24] 2008 was the first complete year of operation of MdP's full network.
[25] It should be highlighted that the contract was executed during the financial assistance program, signed between Portugal and the IMF (International Monetary Fund), EU and ECB (European Central Bank), encompassing the application of a three-year (from 2011 to mid-2014) economic adjustment program.

In line with Nicosia (2001), who documents significant cost-savings at 14% of operating costs attributable to contracting in a sample of over 300 U.S. transit firms, we found that in comparison with the average performance of the two pre-contract years, the average performance of the 2010-2014 contract term documents average improvements of: (*i*) 8.7 percent related to the patronage measured in terms of passenger km, 2.2 percent in average ride length, and 22.7 percent in farebox revenues; (*ii*) a 20.1 percent reduction in operating cost per passenger km, indicating the contract efficiency; and (*iii*) a 41.2 percent increase in the coverage ratio of operating costs by farebox revenues.

5. Summary and Concluding Remarks

There is extensive literature on the benefits and pitfalls of contracting out public transport, and the need to design contracts that align the interests of the parties involved in such deals. However, few works have addressed specific incentive mechanisms. Extant literature highlights the promotion of ridership, and operating cost efficiency gains, as major determinants of competitive contracting out of public transit systems. This paper contributes to this field of literature by developing a bonus/malus (B/M) incentive model.

Using a hypothetical light-rail project and Monte Carlo numerical methods, we show that our B/M model's performance appears sensitive to variability of the B/M drivers, and responsive to changes in the contractual performance factors out of the sub-concessionaire's control. In addition, the MdP light-rail showcase documents, in line with the predictions derived from our model design, that the implementation of a performance-based contract with an incentive bonus/malus mechanism may contribute to promoting ridership patronage, increasing the average ride, and ultimately significantly improving the overall economic

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operating efficiency of the system, gauged by a 41.2 percent increase in the operating costs coverage ratio.[26]

The 2008 financial crisis, the European sovereign debt crisis, and the ongoing Covid-19 pandemic placed world economies under considerable strain, requiring innovative public policies to bring together the public and private sectors. The development of alternative contract awarding mechanisms is thus of increasing importance, namely, those that allow the provision of public transit services that achieve the economic, social and welfare goals underlying governmental contracting out for infrastructure development and operation. We consider this to be an important avenue for future research.

In addition, we think that further application of our incentive performance-based approach model to contracting out public services in general, using different case studies, would be very valuable in testing the robustness of our model.

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[26] The scope of this performance appraisal was necessarily limited by the unavailability of detailed information on the contract execution, proprietary to the concessionaire and the sub-concessionaire.

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Appendix A | Estimators of the isoelastic demand function

The isoelastic demand function to be econometrically estimated under the standard ordinary least squares is specified as:

$$Y = aX^b Z^c \varepsilon \tag{A.1}$$

where Y denotes the reference demand; X and Z the independent variables, such as the ratio of the average individual cost of private transportation to the average individual cost of public transportation, and the activity rate, a is the regression equation independent term; b is the constant elasticity of X on Y; c is the constant elasticity of X on Y; and ε is a random error term with zero mean and constant variance.[27]

The logarithmic transformation of (1) yields:

$$\log Y = \log a + b \log X + c \log Z + \varepsilon \tag{A.2}$$

Estimator of the independent term a:

$$a = anti \log \left(\frac{\sum_{i=1}^{n} \log Y_i - a \sum_{i=1}^{n} \log X_i - c \sum_{i=1}^{n} \log Z_i}{n} \right) \tag{A.3}$$

Estimator of the coefficient b:

$$b = \frac{\sum_{i=1}^{n} \log Y_i \log Z_i - \log b \sum_{i=1}^{n} \log Z_i - c \sum_{i=1}^{n} (\log Z_i)^2}{\sum_{i=1}^{n} \log X_i \log Z_i} \tag{A.4}$$

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[27] In our empirical specification, variable X represents the ratio of the individual average monthly out of the pocket expenses of private transportation (including fuel, parking, and freeway tolls) to the average monthly out of the pocket expenses of public transportation (average cost of a non-subsidized monthly season ticket), and variable Z an activity rate (relationship between the population aged 16 and over to the active population).

Estimator of the coefficient c:

$$c = \frac{-\sum_{i=1}^{n} \log Y_i \log X_i + \log b \sum_{i=1}^{n} \log X_i + a \sum_{i=1}^{n} \left(\log X_i\right)^2}{\sum_{i=1}^{n} \log X_i \log Z_i} \qquad (A.5)$$