QUALITY VS. QUANTITY IN INTEGRATED RAILROADS NETWORK: ROLLING STOCK PROCUREMENT VALUATION FOR THE MADRID-PERPIGNAN HIGH-SPEED LINE

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ABSTRACT

Procurement auctions are widely used to award public contracts more efficiently. However, several factors may affect the outcome of such process. One key to analyzing public procurement auctions are the political conditioning factors linked to government intervention policies, which may constitute a significant source of inefficiencies. This paper focuses on government intervention as a key factor to explain the inefficient outcome of the rolling stock procurement auction for the Madrid-Barcelona-Perpignan high-speed railway line. This paper provides a first attempt to develop a theoretical and practical model with network externalities to rationalize the award of the 2001 high-speed train procurement auction in Spain. The theoretical model presented is a static two-player game whereby the government interacts by determining the quality of trains in order to maximize a social welfare function and the Spanish Railway Company (RENFE) determines the quantity of train units to be awarded to bidders in order to maximize a benefit function. After considering several assumptions, the model yields four possible outcomes based on the bidding firms’ ability to generate domestic labour in similar or different amounts. The differences between the outcome of the 2001 procurement auction and the four possible results obtained from the model underscore the magnitude of political conditioning factors and the impact of poor or biased information.

Key words: rail transport, high-speed railways, procurement auctions, game theory, transparency, regulation.

JEL Classification: L92, H57, D73.
INTRODUCTION

At the end of the 20th century, intent on generating employment at a time marked by increasing airspace congestion and the negative environmental impact of highway, road and air traffic, a few Asian economies such as Japan, South Korea, China and Taiwan, as well as several European Union countries, including France, Germany, Italy and Spain, deemed advisable to promote modern railway infrastructures. In some cases, preference was given to high-speed trains. High-speed trains are considered well-suited for lines with high numbers of passengers in transit. Even though the usual choice is air shuttle services, high-speed trains may be a feasible alternative. The quick growth of the Spanish high-speed railway network was made possible in part thanks to migrant workers coming from Africa, East Europe and South America.

In 2000, the Spanish state-owned railway company (RENFE) announced a bidding process to award the supply and integrated maintenance services of the trains and facilities associated with the Madrid-Barcelona-French Border-Le Soler (Perpignan) high-speed line (797 km / 495 mi), with an initial budget of 667,123,436 euros to purchase high-speed rolling stock. Based on traffic demand studies, specifications covered both the design and manufacture of 26 to 40 standard gauge high-speed trains equipped with 8-11 coaches each, and maintenance expenses. It is assumed that trains lifetime is just over 30 years (1) and maintenance expenses on top of the initial budget were estimated at 89% of the initial budget. The layout for this line should be such that trains would run at a speed of anywhere between 300 and 350 km/h (187-219 mph) and link together the cities of Madrid and Barcelona in less than 2.30 hours.

To conduct the procurement auction, a Contract Committee was created to draft the corresponding assignment proposal. The Committee was formed by both senior officials from the Spanish Ministry of Public Works and managers from RENFE. Negotiations for proposals began on March 2001, allowing only five working days for completion. Bidders were advised to modify their proposals as to include a provision whereby RENFE would have a 20% share in rolling stock manufacturing and 50% in train maintenance for a 14-year period using domestic labour.

BACKGROUND AND LITERATURE REVIEW

In this paper, a two-player game model was designed to analyze the outcome of the high-speed train procurement auction for the new Madrid-Barcelona-French Border high-speed line. Under this model, the government interacts by determining the quality of rolling stocks with a view to maximizing a social welfare function. The Spanish Railway Company (RENFE) maximizes profit and determines the amount of train units to be assigned to bidders. In addition, it is assumed that some positive externalities are generated around the high-speed network. The actual final assignments were compared against the alternative outcomes predicted by the model.

The results obtained were subsequently used to assess and measure any inefficiencies associated with government interaction and with the fact that the information available was imperfect. Such irregularities have already been addressed in a number of works: (2, 3), (4), (5, 6), and (7). Favouritism in auctions has been particularly analyzed in (8). The use of combinatorial auctions to increase efficiency in transportation services has been analyzed by (9) and (10). Other authors have also studied the procurement auction process utilizing quality as a key variable: (11), (12) or (13). Nevertheless, previous works have mainly focused on theoretical assumptions and generally resorted to simulations to bring those assumptions closer to reality.

Overview of the Spanish railways network

By the end of 2013, the Spanish railways network spanned 15,772 kilometres (9,796 mi), 63 percent of which were electrified (suburban railroads, subways and trams not included). Three types of track
gauges are used in Spain: the standard UIC (International Union of Railways) gauge (1.435 m / 4'8.5"), the national broad gauge (1.668 m / 5'6"), and the narrow gauge (1.00 m / 3'6"). All standard international gauge lines are currently dedicated to high-speed trains. The high-speed Madrid-Barcelona line (623 km/384 mi) makes up a significant part of the new Spanish high-speed UIC standard gauge railways network (see Figure 1). In late 2013 the Spanish high-speed network was covering 3,199 kilometers (1,987 mi); the lines are double-tracked, fully electrified at 25 kV (A.C.) and equipped with ERTMS signalling systems (European Rail Traffic Management System). Out of these 3,199 kilometers, 857 km (532 mi) of broad gauge are currently being replaced with UIC gauge. On the other hand, there remains in Spain 11,856 kilometres of traditional broad gauge railways, 55 % of which are electrified at 3 kV (D.C.), and narrow gauge lines stretching out over 1,574 kilometres, 40% of which are electrified at 1.5 kV (D.C.). By the end 2013, the Spanish high-speed network was equipped with 25 junctions for track gauge changeover. The Madrid-Le Soler (Perpignan) high speed line completely entered service in 2013.

![Figure 1: The Spanish high-speed railroad network, 2014.](source: Adif, and own elaboration.)

To address these issues, the work is organized as follows: the following section looks at the pre-selected bidders in the 2001 auction and the final offers. Based on the bids submitted and the outcome of the auction, other sections of this paper describe the model that explains the behaviour exhibited both by the government and RENFE. The model makes the extreme assumption that the government has total control over the quality choice in order to clearly illustrate the effects of information and expertise asymmetries, and that RENFE has the final word on the number of train units to be purchased. The last section reports empirical results and assesses the different results obtained for the two options under consideration. The first option assumes that only two of the three
final candidates in the procurement auction will generate domestic employment. In the second option, the three companies are capable of generating domestic employment. This difference was accounted for in order to provide insight into the impact of political conditioning factors that are likely to affect the procurement auction. The paper ends with the conclusions drawn from this work.

PROPOSALS AND REQUIREMENTS IN THE 2001 PROCUREMENT AUCTION

The groups that were invited and pre-selected to bid in 2001 were: Breda Construzioni Ferroviarie and Ansaldo Transporti (Ansaldo-Breda); Siemens; Patentes Talgo and Daimler Chrysler Rail Systems (Talgo-ADtranz); and Alstom Transport and Construcciones y Auxiliar de Ferrocarriles (Alstom-CAF). The documentation submitted by Bombardier ANF was rejected due to the formal defects contained therein. Finally, the Ansaldo-Breda group decided to opt out of the procurement process.

In the 2001 bid, although at first sight the high speed rolling stocks built by the pre-selected groups may be considered mutually substitutable, it would be advisable to examine in greater detail the railway services required for the new line and certain features of the pre-selected high-speed rolling stocks. The remaining three companies participating in the process proposed a series of basic specifications that may be summarized as follows:

i)-Siemens: top speed 350 km/h (219 m.p.h.); distributed traction along the train. A similar series (ICE 3-Velaro) runs at a commercial speed of 234 km/h (146 m.p.h.) on the Köln-Frankfurt/Main high-speed line.

ii)-Talgo-Adtranz: top speed 330 km/h (206 m.p.h.); traction equipment concentrated in two locomotives; not yet approved, as it was only a prototype.

iii)-Alstom-CAF: peak speed of 320 km/h (200 m.p.h.); traction equipment concentrated in two locomotives. Commercial services are provided between Lorraine TGV and Champagne TGV (14) at a commercial speed of 279 km/h (174 m.p.h.) over tracks with null gradient on the Paris-Strasbourg high-speed line.

Only two out of three adhered to the guidelines set by the Infrastructures State Secretariat (Ministry of Public Works). These were Siemens and Talgo-Adtranz, whose final proposals included the express agreement to contract 50% of train maintenance services with RENFE personnel during a 14-year period, a commitment that the Alstom-CAF group did not expressly agree to. We should bear in mind that, at the time of the procurement auction, the Alstom-CAF consortium had some 5,000 employees in Spain, whereas the Talgo-Adtranz group had approximately 1,500 and Siemens only 400. Therefore, in order to execute the tasks associated with the procurement auction under consideration, the winner would necessarily have to generate additional employment in the sector. However, this condition could be harder to meet for Alstom-CAF, since it meant replacing its own employees with those provided by RENFE.

To achieve full efficiency in the new high-speed Madrid-Barcelona-French Border section, it was necessary to buy new rolling stock that may fulfil at least one of the following three requirements:

1) the basic premise was that the new trains should travel non-stop from downtown Madrid to downtown Barcelona in a maximum of 2.30 hours, at an average speed of 250 km/h (155 m.p.h.), and thus be in a position to compete against air travel; travel time is expected to drop down to two hours in the near future; 2) trains should both link Madrid-Barcelona-Figueres and make six intermediate stops in a reasonable amount of time; and 3) shuttle trains should cover quickly partial journeys only between the towns found along the way.

On the other hand, it is reasonable to think that the most relevant feature of quality is the ability to attain the highest speed while guaranteeing safety. Evidence of speed records for the new Spanish lines and three new trains was submitted during the final pre-selection phase: during the tests performed on Spanish tracks, maximum speed reached by the Siemens train (ICE3-Velaro) was 404 km/h (252 m.p.h.), with an acceleration of 0.23 m/s²; the Talgo-Adtranz train (Talgo-350 Series 102 and 112) reached a speed of 365 km/h (227 m.p.h.), with an acceleration of 0.27 m/s²; and maximum
speed reached by the Alstom train was 357 km/h (222 m.p.h.), with an acceleration of 0.21 m/s². Hence, ICE-3 will likely meet requirement 1) better than Talgo or Alstom. In terms of speed, neither Talgo nor Alstom can compete against the ICE-3 as far as requirement 1) goes. Moreover, it is apparent that Talgo-350 is better placed to fulfill requirement 2) than Alstom, since Talgo’s acceleration rates are higher. ICE-3 appears to be the most ill-suited to meet requirements 2) or 3). Under such conditions, it is possible to establish a correspondence between trains and requirements: ICE-3 to 1), Talgo to 2), and Alstom or other kinds of shuttles to 3).

Consequently, in terms of travel time, it is safe to say that neither type of rolling stock is a perfect substitute.

A MODEL FOR HIGH SPEED ROLLING STOCK SELECTION

This section aims to model the award of high-speed rolling stock from a microeconomic perspective. Two main options are presented herein. One option is intended to suggest an explanation of the decision-making process adopted during the Madrid-Barcelona-French Border high-speed train procurement auction by assuming the Contract Committee’s perception of the different attitudes displayed by all three corporations about the possibility of hiring RENFE personnel to perform construction and maintenance tasks and creating more domestic jobs. In this particular case, it is assumed that one of the three companies participating will not generate any. The other option assumes that the three bidding companies could create domestic employment.

Typically, the literature available on public procurement and regulation deals with the procurer (the government) as if it were a Stackelberg leader who presents the agent with a range of options to choose from. Here, by following (11) and (12), the decision-making process leading to the adoption of a new high-speed train program will be viewed as a two-player static game between the Spanish government and the Spanish state-owned railway company (RENFE). During the procurement process, the Contract Committee acts on behalf of the Spanish government, while the Spanish Railway Company (RENFE) is represented by its Board of Directors. The model makes the extreme assumption that the government exerts total control over the quality choice in order to illustrate the effects of asymmetry on information and expertise. Generalizing, the model presumes \( n \) bidders participating in the procurement auction, and two players: the government as \( \text{Agent-1} \) and the Spanish State Railway Company (RENFE) as \( \text{Agent-2} \). The sequential nature of the decision process assumes that the government, by means of the Contract Committee, first (during stage 1) chooses a quality \((q)\) program (although the model is capable of choosing the optimal quality endogenously, in this particular case \(\text{Agent-1} \) determines exogenously the quality of the rolling stock types), and then (stage 2) maximizes a social welfare function \((W)\). At stage 3, by choosing a certain funding level \((B)\), RENFE’s Board of Directors determines the quantity \((x)\) of train units that maximizes \(V(q, x) - C(q, x)\).

\(C(q, x)\) denotes the cost of purchasing high speed rolling stocks, where \(q\) stands for quality and \(x\) for the amount. \(V(q, x)\) denotes the economic value of the high-speed trains program \((q, x)\) to \(\text{Agent-2}\) expressed in euros: \(p \cdot y(q, x)\), where \(p\) is the price level, which are presumed constant, and \(y\) is the total value in real terms added to domestic production by the High-Speed Division of \(\text{Agent-2}\), which produces trips by means of rolling stocks.

A high-speed rolling stock program will be assumed to be fully described by two nonnegative real numbers, \((q, x)\), where \(q\) denotes the quality of trains and \(x\) denotes the number of units purchased. The program \((q, x)\) is a second-best, given budget \(B\), if the \(\text{Agent-2}:\)

\[
\underset{(q,x) \in \mathbb{R}^+}{\text{Maximizes}} \left\{ V(q, x) \right\}
\]

\(\text{Subject to } C(q, x) \leq B\)
Being $\mathbb{R}^2$ the set of positive real numbers with two dimensions. Modelling this decision process requires that we make the following nine assumptions:

1) Government target: We will assume that the social welfare function ($W$) to be maximized by Agent-1 coincides with the real per capita GDP of the economy in the long run.

2) Network effects: We assume that the capability of high-speed railways to transport the maximum number of passengers depends exclusively on the quantity and quality of its rolling stocks. The present analysis also abstracts away other factors such as infrastructures, equipment, personnel, or level of training. As mentioned before, there exist three kinds of interconnected railway networks in Spain, apart from their connections to other transportation systems. This fact could have an exponential network effect: it influences the quality of connections between systems, and the number of connections is exponential to the number of systems (network size). Additionally, integrative technologies such as communication and information systems enhance the network effect causing jointly increasing returns.

3) Network quality modelling: In view of the above, for the purposes of our stylized model, ‘quality’ is the variable used to describe the technical specifications of the rolling stock systems. The government has the expertise to fully assess, choose and determine the quality and technical specifications of new trains. We assume that the degree of quality in the network is described by a scaled measure denoted by $Q$, which expresses a positive network externality related to the quality of train units, $q_i$, by means of the following multiplicative form:

$$Q = \prod_{i=1}^{n} q_i$$  \hspace{1cm} (2)

4) The network externality: Because the value of networks stems from the number of users, externality $Q$ not only depends on quality $q_i$ but also on the size of the network itself, and hence on the train unit quantities $x_i$. In this sense, the authors (15) and (16) define the capability ($C$) of each rolling stock system within the network as a direct multiplication of its quantity and quality: $C_i = q_i \cdot x_i$. We assume that, in the event that an exponential network effect takes place, the function of capability will have the following form:

$$C_i = q_i \cdot x_i = x_i^{(1+\theta_i, q_i, -\alpha_i)}$$  \hspace{1cm} (3)

$\theta_i$ and $\alpha_i$ being the two positive parameters emphasising the exponential effect. This form of exponential network effect allows us to obtain globally constant returns in the production function of Agent-2. By rearranging the equation (3), we obtain:

$$q_i = x_i^{\theta_i, q_i, -\alpha_i}$$  \hspace{1cm} (4)

By solving this equation, we will obtain:

$$x_i = q_i^{1/(\theta_i, q_i, -\alpha_i)}$$  \hspace{1cm} (5)

That is, network externality $Q$ reveals a relationship between the quality of train systems ($q_i$) and the acquired quantity of train units ($x_i$). Based on Equation (5) we may infer that the relationship is only increasing for qualities $q_i > \alpha_i / \theta_i$. In this particular case, it is not possible to isolate $q_i$ from equations (3) or (4). But taking natural logarithms in (5) and developing $lnq_i$ by means of a Taylor series, we obtain an approximate value for $q_i$:

$$q_i \approx \frac{\alpha_i \cdot \ln x_i - 1}{\theta_i \cdot \ln x_i - 1} = q_i(x_i)$$  \hspace{1cm} (6)

and are thus able to rewrite network externality $Q$ as $Q[q_i(x_i)]$.

5) Production function of the Spanish Railroads Company: As noted in (17) and (18), transportation (including high-speed transportation) is used as an intermediate input. For Agent-2 we propose, following (19), a production function formulation to aggregate the quantities and qualities of the various high-speed rolling stock systems into a single measure of high-speed railways output. If, for simplicity’s sake, we do not consider directly as arguments any inputs other than some
intermediate goods devoted to high-speed railway transportation, measured in terms of rolling stocks \((x_i)\), then the production function of the High-Speed Section of Agent-2 may be expressed as follows, considering it separable in \(Q\):

\[
y = Q[q_i(x_i)] \cdot \prod_{i=1}^{n} x_i^{\alpha_i}
\]

(7)

Where the train units \(x_i\), play the role of intermediate inputs. The term \(Q[q_i(x_i)]\) denotes the network externality associated with a Hicks neutral total factor productivity, which depends on the quality \(q_i\) and quantity \(x_i\) of the acquired train units. Although the term \(Q\) is associated with the network externality and hence normally increasing returns are induced, following (11), we can consider that production function of Agent-2 embodies globally constant returns. This is because in our particular case the three kinds of rolling stock are neither perfectly substitute nor complementary inputs.

Then, the Equation (7) must be subjected to: \(\sum_{i=1}^{n} \alpha_i < 1\) because, under Assumption 4, \(Q\) also depends on \(x_i\). Considering the equations (2), (4) and (5) we can also write Equation (7) in the form:

\[
y = \prod_{i=1}^{n} q_i \cdot \prod_{i=1}^{n} x_i^{\alpha_i} = \prod_{i=1}^{n} x_i^{\theta q_i}
\]

(8)

where it must fulfil that \(\sum_{i=1}^{n} \theta q_i = 1\) to keep constant returns.

6): Budgetary level: Let us assume that Agent-2 can commit to a fixed budget level \(B\) for a program prior to the point in time when Agent-1 chooses quality. Budgetary level \(B\) is deduced from traffic demand estimates made by Agent 2 on the Madrid-Barcelona French Border corridor, once air, road, and traditional railway passenger traffic have been accounted for. The results obtained indicate that Agent-2 needs anywhere between 26 and 40 trains units to meet current traffic demand. Since ours is a supply-side model, we may assume that the budget for high-speed railways is determined exogenously.

7): Quality choice: Agent-2’s Contract Committee influenced by Agent-1 rates the quality \((q_i)\) of train units on a scale of 0 to 55. We will assume the normalization of these qualities in the form:

\[
\sum_{i=1}^{n} q_i = 1.
\]

8): Cost constraint: In addition to the cost of buying rolling stocks \((AC = \sum_{i=1}^{n} p_i \cdot x_i)\), maintenance costs \((MC)\) are assumed to be increasingly proportional to the direct multiplication of quality \((q)\) and train units \((x)\): \(MC = \sum_{i=1}^{n} \mu_i q_i x_i\), where \(\mu_i\) are positive parameters. Furthermore, the value of maintenance costs at a certain point during the lifetime of rolling stocks acquired is: \(MC = \sum_{i=1}^{n} \rho_i \cdot p_i \cdot x_i = \rho \sum_{i=1}^{n} p_i \cdot x_i\), where \(\rho_i\) is the individual ratio between the maintenance and acquisition costs, corresponding to the train units \(x_i\), and \(\rho\) is an index number, average of \(\rho_i\) (in our case, \(\rho=0.89\)). Accordingly, we can formulate the following equation: \(MC = \rho \cdot AC\), and identifying coefficients we obtain the value for \(\mu_i\) parameters: \(\mu_i = \rho \cdot p_i / q_i\), which reveals the existence of an increasing relationship between price and quality: \(p_i = \mu_i \cdot q_i / \rho\). Given that the total cost is: \(CT = AC + MC\), the total cost function will be:

\[
CT(q_i x_i) = \sum_{i=1}^{n} (p_i + \mu_i q_i)x_i \leq B
\]

(9)

where \(p_i\) is the price for each train unit corresponding to group \(x_i\).
9): Production function of rolling stock: At the same time, intermediate goods \((x_i)\) would be assembled and manufactured using domestic labour \(l_i\) and physical capital \(k_i\) provided by the selected companies, following a production function: \(x_i = f(k_i, l_i)\), where for the sake of simplicity we will assume that domestic labour productivity is the same and remains constant in all three companies: \(x_i/l_i = \Phi > 0\).

By substituting this result in the system formed by the equations (8) and (9), the program \((q, x)\) expressed by means of system (1) can now be written as:

\[
\begin{align*}
\text{Maximize} & \quad y = \Phi \prod_{i=1}^{n} l_i^\theta d_i, \\
\text{Subject to} & \quad \Phi \sum_{i=1}^{n} (p_i + \mu_i \cdot q_i) l_i \leq B
\end{align*}
\]

The result of maximizing system (10) will depend on whether the amount of Spanish domestic employment \((l_i)\) is the same or not for each company and whether any of them fail to generate domestic employment.

**THEORETICAL RESULTS**

Once the maximization problem of the model (8) was solved, the optimal number of train units selected varied depending on each of the following four cases:

Case A) Group \((x_n)\) does not generate domestic employment, but the other pre-selected firms employ a similar amount of domestic labour \((l_i = l_j)\). The optimal number of \(x_i\) train units to be purchased from each group is:

\[
x_{iA} = \frac{B}{\sum_{i=1}^{n-1} (1 + \rho_i) p_i}, \quad \forall i = 1, \ldots, n - 1
\]

Case B) Group \((x_n)\) does not generate domestic employment and the other pre-selected firms do not employ similar amount of domestic labour \((l_i \neq l_j)\). In this case, the optimal number of train units to be acquired is:

\[
x_{iB} = \frac{q_i \cdot B}{(1 - q_n) (1 + \rho_i) p_i}, \quad \forall i = 1, \ldots, n - 1
\]

Case C) All groups \((x_1, x_2, \ldots, x_n)\) generate domestic employment in similar amount \((l_i = l_j)\). The optimal selection is:

\[
x_{iC} = \frac{B}{\sum_{i=1}^{n} (1 + \rho_i) p_i}, \quad \forall i = 1, \ldots, n
\]

Case D) All groups \((x_1, x_2, \ldots, x_n)\) generate domestic employment in different amount of labour \((l_i \neq l_j)\). In this case, we obtain new results for Agent-2’s choice on the quantity of train units:

\[
x_{iD} = \frac{q_i \cdot B}{(1 + \rho_i) p_i}, \quad \forall i = 1, \ldots, n
\]
### TABLE 1 Specifications and Appraisal of the Different High Speed Train Proposals

<table>
<thead>
<tr>
<th></th>
<th>Alstom-CAF 1Level</th>
<th>Alstom-CAF 2Level</th>
<th>Siemens (Basic) 7 railcars</th>
<th>Siemens (Velaro E) 8 railcars</th>
<th>Talgo-ADtranz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top proposed speed (km/h)</td>
<td>320</td>
<td>320</td>
<td>350</td>
<td>350</td>
<td>330</td>
</tr>
<tr>
<td>Power (Kw)</td>
<td>7,500</td>
<td>8,960</td>
<td>8,800</td>
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<tr>
<td>Train mass (T.)</td>
<td>393</td>
<td>424</td>
<td>435</td>
<td>425</td>
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<tr>
<td>Acceleration 0-300 km/h</td>
<td>387</td>
<td>351</td>
<td>366</td>
<td>357</td>
<td>298</td>
</tr>
<tr>
<td>Number of Seats</td>
<td>303</td>
<td>458</td>
<td>332</td>
<td>404</td>
<td>318</td>
</tr>
<tr>
<td>Train price without commercial equipment (Euros €)</td>
<td>20,674,741</td>
<td>25,298,960</td>
<td>21,001,490</td>
<td>23,507,493</td>
<td>19,849,491</td>
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<td>Cost standard commercial equipment by train unit (€)</td>
<td>1,323,440</td>
<td>1,499,020</td>
<td>1,356,290</td>
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<td>Train price with standard commercial equipment (€)</td>
<td>21,998,181</td>
<td>26,797,980</td>
<td>22,357,780</td>
<td>24,945,343</td>
<td>21,189,921</td>
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<td>Cost / seat with standard commercial equipment (€ / seat)</td>
<td>72,601</td>
<td>58,511</td>
<td>67,343</td>
<td>61,746</td>
<td>66,634</td>
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<tr>
<td>Total combined cost train and maintenance 14 years standard commercial equipment (€)</td>
<td>46,717,981</td>
<td>55,075,870</td>
<td>40,067,780</td>
<td>43,985,343</td>
<td>38,234,921</td>
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<td>Maintenance cost including cleaning / km, (500,000 km / year), (€ / km)</td>
<td>3.53</td>
<td>4.04</td>
<td>2.53</td>
<td>2.72</td>
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<tr>
<td>Maintenance cost / seat km (14 years) (€)</td>
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<td>0.01</td>
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<tr>
<td>Combined cost standard commercial equipment / seat km. (14 years) (€)</td>
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<td>Appraisal of technical factors (scores)</td>
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<td>Appraisal of functional factors (scores)</td>
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<td>Appraisal of operating factors (scores)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total technical + functional + operating factors (scores)</td>
<td>44</td>
<td>44</td>
<td>47</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>Economic appraisal (scores)</td>
<td>71</td>
<td>70</td>
<td>89</td>
<td>100</td>
<td>92</td>
</tr>
<tr>
<td>Total appraisal (scores)</td>
<td>57.5</td>
<td>57.0</td>
<td>68.0</td>
<td>73.5</td>
<td>68.5</td>
</tr>
</tbody>
</table>

Source: Directorate General of the Spanish Secretariat of State for Infrastructures (2001), April 8, 2001

Note: 1 km = 0.62 mi; 1 km/h = 0.62 m.p.h.

### DATA AND EMPIRICAL RESULTS

In order to apply the above model to a real-life scenario, we will consider that the number of bidders is 3 ($n=3$), and hence $q_n = q_3$. We consider that Bidder 1 is Siemens, and the unit price for the Siemens train, its quality and the selected quantities are $p_i$, $q_i$, and $x_i$, respectively. The same applies to bidders.
2 and 3, respectively: Talgo-ADtranz, \((p_2, q_2, x_2)\) and Alstom-CAF, \((p_3, q_3, x_3)\). The model has been applied using data from several databases: (20) and (21). At first, five train versions were considered in the procurement auction, and the contract committee, influenced by the government, put in place a system of weights and balances for the different factors affecting quality (see Table 1).

Tables 1 and 2 show the scores obtained for each proposal based on technical, functional and operating considerations. There is very little dispersion between scores, which range from 44 to 47 points for Alstom-CAF and Siemens, respectively. Siemens and Talgo-ADtranz obtained the highest ratings from the Contract Committee in technical and economic terms. This contrasts with the fact that proposals differed greatly with respect to certain key variables such as commercial equipment or number of seats per train. After careful consideration, only three versions were selected (Table 2), one for each company. Siemens Basic was rejected in favour of Siemens Velaro on account of the number of seats, and Alstom-CAF 2-Levels was deemed too expensive and was rejected in favour of 1-Level because their configuration would limit the ability to provide quality services on the upper story and the mobility of older people and those with physical disabilities.

### TABLE 2 Input Data for the Model

<table>
<thead>
<tr>
<th>Proposals</th>
<th>Siemens Velaro (bidder 1)</th>
<th>Talgo-ADtranz (bidder 2)</th>
<th>Alstom-CAF 1-Lev (bidder 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price per train unit (€)</td>
<td>(p_1 = 23,507,493)</td>
<td>(p_2 = 19,849,491)</td>
<td>(p_3 = 20,674,741)</td>
</tr>
<tr>
<td>Points for technical, functional and operating factors (*)</td>
<td>47</td>
<td>45</td>
<td>44</td>
</tr>
<tr>
<td>Normalized quality coefficients</td>
<td>(q_1 = 0.346)</td>
<td>(q_2 = 0.331)</td>
<td>(q_3 = 0.323)</td>
</tr>
<tr>
<td>(\mu_i) multipliers</td>
<td>(\mu_1 = 60,467,250.78)</td>
<td>(\mu_2 = 53,371,743.17)</td>
<td>(\mu_3 = 56,967,552.6)</td>
</tr>
<tr>
<td>Maintenance Costs / Rolling Stock Acquisition Cost individual Ratio ((\rho_i))</td>
<td>(\rho_1 = 0.76)</td>
<td>(\rho_2 = 0.80)</td>
<td>(\rho_3 = 1.12)</td>
</tr>
<tr>
<td>Rolling stock acquisition cost (€)</td>
<td>(AC = 667,123,436)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance costs (€)</td>
<td>(MC = 593,739,858)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total budget committed by RENFE (€)</td>
<td>(B = 1,260,863,294)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance Costs/Rolling Stock Acquisition Cost average Ratio</td>
<td>(\rho = 89%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(\rho\) Maximum score = 55 points

Source: RENFE and own elaboration

The empirical results of the model for committed budget \(B\) indicate that, in the above cases, the optimal number of train units to be acquired is approximately 31. However, since the number of outbound journeys is often the same as the number of returning journeys, RENFE will purchase an even number of train units. On the basis of these appraisals, RENFE’s Board of Directors awarded the auction for the manufacture of 32 high-speed trains for the Madrid-Barcelona line. The remaining unit should be awarded according to the principle of minimum budget modification (see Table 3).

### TABLE 3 Train Units Selection and Budget Modifications in Each Case

<table>
<thead>
<tr>
<th>Cases</th>
<th>Siemens ((x_1))</th>
<th>Talgo-ADtranz ((x_2))</th>
<th>Alstom-CAF ((x_3))</th>
<th>Initial Budget Modification *</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>16</td>
<td>16</td>
<td>0</td>
<td>€ 26,588,308</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>17</td>
<td>0</td>
<td>€ 22,930,306</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>€ 12,892,796</td>
</tr>
<tr>
<td>D</td>
<td>11</td>
<td>12</td>
<td>9</td>
<td>€ 15,725,548</td>
</tr>
</tbody>
</table>

\(\rho\) The budget modification is the difference between the production cost of each case, according to its composition, and the initial budget committed by RENFE: \(\Sigma (p_i x_i) – AC\).

Source: Own elaboration.
In the course of the actual procurement auction (case A in Table 3), RENFE decided to request one additional unit, bringing the total number of units to be built to 32: 16 train units by Siemens and 16 by Talgo-ADtranz. It is worth mentioning that this outcome is obtained under the assumption that only Siemens and Talgo-ADtranz are capable of generating additional domestic employment. Under this assumption, the results obtained for cases A and B under Option 1 are consistent with the final award by the Contract Committee, i.e. Siemens and Talgo-ADtranz. In this procurement process, the bidder that was left out, Alstom-CAF, was not commissioned to build any high-speed trains.

According to the model, the actual outcome of the procurement auction (Case A), which assumes an equal amount of domestic labour, 16 trains are assigned to Siemens and 16 to Talgo-ADtranz; the budget modification was worth €26,588,308. Case B assumes a different amount of domestic labour for each of the two winning companies. As a result, 15 trains would have been awarded to Siemens and 17 to Talgo-ADtranz. In this particular case, the budget modification amounted to €22,930,306. In both cases A and B, the model makes certain assumptions pertaining to domestic employment that made it possible to reject the Alstom-CAF bid. Rendering such decision based only in technical and financial criteria would have been much more difficult. This could imply that the government may consider the ability or inability to generate additional domestic employment as a discriminating element. However, this last statement is not clear if we consider that Alstom-CAF is now creating domestic jobs building non high-speed trains. Option 2 assumes that all three bidders have the ability to generate additional domestic employment. The fact that Alstom-CAF is not eliminated is a consequence of using a more reasonable assumption. Results obtained in Case C, assuming an equal amount of domestic labour, are 10 units to Siemens, 12 to Talgo-ADtranz, and 10 to Alstom-CAF. Budget modification amounted to €12,892,796. Case D does not assume an equal amount of domestic labour for the three groups. Results for this case are 11 train units to Siemens, 12 train units to Talgo-ADtranz, and 9 train units to Alstom-CAF. Budget modification amounted to €15,725,548. Following (2) the diversification of the technological risk is the best option for avoiding mono-dependence. The small differences in train unit allocation among the three corporate groups in cases C and D are consistent with the insignificant dispersion of the Contract Committee’s scores for technical factors and moderate price differences between proposals (see Table 2).

CONCLUSIONS

The differences between the actual outcome of the procurement auction and the results obtained in all four cases analyzed underscore the magnitude of political conditioning factors and consequences of working with poor or biased information. The empirical results of the model for the committed budget indicate that, in the four cases above, the optimal number of train units to be acquired is approximately 32. B and D are both the optimal and most realistic cases, since it is very likely that the three bidding companies may not generate the same amount of domestic labour in real life, Case D being more efficient due to its budget modification being smaller. The difference between cases B and D lies in the very definition of domestic labour: whether by domestic labour we mean the jobs assigned exclusively to RENFE’s personnel (Case B) or those pertaining to the Spanish labour force in general (Case D). These results differ greatly from the actual outcome of the procurement auction, where 16 units were awarded to Siemens, 16 to Talgo-ADtranz and none to Alstom-CAF, resulting in a budget modification of €26,588,308 (Case A).

The paper analyzes the circumstances in which the procurement auction process and its resolution took place. Everything indicates that the award of public contracts can be biased when certain relevant aspects are not taken into consideration in the assessment. For instance, commercial experience in high-speed trains was underestimated in this auction. In recent years, most countries have adopted regulations to prevent the perverse effects of irregular conducts by participating companies. Examples of the government’s awareness of these issues are the measures developed to foster competition and the right to tender. However, there are no mechanisms in place to counter the
problems arising due to arbitrary decisions based on non-transparent conduct or lack of reliable information. The example analyzed in this paper shows that non-transparent behaviour can be detrimental to the general or at least to the sector’s welfare. In this sense, it would be advisable to resort to the collaboration of independent technicians, practitioners and experts, and to transparent decision-making mechanisms. The teaching of this article may also be useful for policymakers and theorists.

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REFERENCES


