# A NEW WAY OF REPRESENTING TENDERING DATA IN A COMPETITIVE BIDDING STRATEGY

Pablo Ballesteros-Pérez

*Depuración de Aguas del Mediterráneo S.L. (DAM)*

M. Carmen González-Cruz

Juan Pascual Pastor-Ferrando

Marta Fernández Diego

*Universidad Politécnica de Valencia*

## Abstract

Research in the area of competitive bidding strategy models has been in progress since the 1950s and numerous competitive bidding strategy models have been developed that predict the probability of a bidder winning an auction. However there is no generally acceptable approach to solve real bidding problems, in particular the models based on the theory of Games, Decision Analysis and Operational Research are difficult to apply to real-world business contexts largely because of the complex mathematical formulations used in the models and/or because the models do not suit the actual practices.

The present work presents a new practical tool that can help potential bidders improve their competitive bidding strategies and increase their chances of winning a contract. The graphic tool described here tries to move away from previous bidding models which attempt to describe the result of an auction or a tender process by means of studying each possible bidder with probability density functions.

As an illustration, the tool is applied to three practical cases. Theoretical and practical conclusions on the great potential breadth of application of the tool are also presented.

***Keywords****: bid; tender; auction; construction; score; graph*

## Resumen

La investigación en modelos de licitación ha aumentado desde la década de los 50, desarrollándose modelos de estrategias competitivas que predicen la probabilidad de conseguir la adjudicación de un determinado contrato en una subasta.

Sin embargo no existen enfoques adecuados para resolver problemas reales de licitación. En particular, los modelos basados en la teoría de juegos, análisis de decisiones y la investigación operativa, son difíciles de aplicar a contextos reales de negocio, en gran parte debido a las complejas formulaciones matemáticas utilizadas en los modelos y/o porque los modelos no se adecuan a las prácticas reales. Este trabajo describe una nueva herramienta que ayuda a los licitadores a mejorar sus estrategias competitivas en licitaciones. Esta herramienta es un gráfico de fácil utilización que permite el uso de herramientas complejas de análisis de decisión en la Licitación competitiva La herramienta gráfica descrita aquí intenta alejarse de la concepción de modelos de licitación previos que intenta describir el resultado de una subasta o proceso de concurso por medio de estudiar a cada posible licitador con funciones de densidad de probabilidad.

La herramienta se aplica a tres casos prácticos presentándose también las conclusiones acerca del amplio potencial de la aplicación de la herramienta.

***Palabras clave:*** *oferta; licitación; subasta; construcción; puntuación; gráfico*

## 1. Introducción

The volume of economic transactions conducted by competitive bidding gives importance both to the study of auctions as a part of basic research in economics and management science, and to the evaluation of assistance bidding practitioners can get from the advances made in auction theory (Rothkopf & Harstad, 1994).

Because of the complexity in the application of such models to public tenders (Rothkopf & Harstad, 1994; Skitmore, 2002), where multiple technical and financial criteria are involved, there is still a need for the development of new tools that help decision makers and improve the selection process of candidate contractors in any kind of public tender, thus extending their field of application to tender contests.

The present work presents a new practical tool that can help potential bidders improve their competitive bidding strategies and increase their chances of winning a contract. This tool constitutes the first of four kinds of graphs that will enable bidders to place their bids thanks to previous bidding experiences and according to simple statistical procedures.

## 2. Main previous works

The large literature on bidding theory and models (see Stark and Rothkopf, 1979), for an early bibliography) is replete with what can be termed ‘the statistical hypothesis’ in that auction bids are assumed to contain statistical properties such as fixed parameters and randomness (Skitmore, 2002).

The first contributions (e.g., Friedman, 1956) assumed that each bidder drew bids from a probability distribution unique to that bidder, with low-frequency bidders being pooled as a special case.

Pim (1974) analysed a number of projects awarded to four USA construction companies. His study indicated that the average number of projects acquired is generally proportional to the reciprocal of the average number of bidders competing - the proportion that would be expected to be won by pure 'chance' alone. That suggested an extremely simple ‘equal probability’ model in which the expected probability of entering the lowest bid in a k-size auction, that is, an auction in which k bidders enter bids, is the reciprocal of k.

Later work by McCaffer & Pettitt (1976) and Mitchell (1977) for example, assumed the probability distributions to be non-unique and homogeneous, enabling a suitable distribution shape to be empirically fitted (uniform, in the case of McCaffer and Pettitt) and the derivation of order statistics based on an assumed (normal) density function.

Since then, most of the bidding literature has been concerned with setting a mark-up, *m*, so that the probability, *Pr(m)*, of entering the winning bid reaches some desired level. Several models have been proposed for calculating *Pr(m)* (Skitmore, Pettitt, & McVinish, 2007), among them, four main approaches have been: Friedman’s (1956), Gates’ (1967), Carr’s (1982) and Skitmore’s (1991) models.

All these models are based on the same statistical model but differ in their detailed assumptions of its specification. Nevertheless, previous work in auction bidding has to a large extent been carried out without any real supporting data. In fact, in the context of construction contract auction bidding, it has been doubtful that sufficient data can be mustered for each bidder for any effective predictions to be made (Skitmore, 2002).

The graphic tool described later will enable bidders representing bidding historical data and inferring patterns of competitors’ behavior in a way not studied before. Whereas previous models are mainly based on probabilistic description of groups of single bidders, the new bid tender forecasting model (BTFM hereinafter), whose first part is constituted by the graphical tool described afterwards, will describe group patterns while bidding.

This alternative viewpoint will allow us: (1) to study bidding behaviors with a significant small database compared to previous works; (2) to forecast the probability of getting a particular position within the group of competitors, and (3) to analyse time variations between tenders. The advantages of the new model we are going to explain solve the major problems that almost all of the previous models currently have.

However, due to the lack of space needed to show the whole BTFM, in this paper only the first model's tool will be shown: the iso-Score Curves Graph, which enables us to represent, on a convenient canvas, the bidding data and statistical functions that will be explained in upcoming articles.

## 3. Background. Auctions vs Tenders

In general there are many different forms of auctions and several useful ways of classifying these variants. A "standard" auction means one in which the winner is the highest bidder among potential buyers, or the lowest bidder among potential sellers. The distinction between contexts in which bidders are competing to buy and to sell is relatively unimportant: there is an almost perfect correspondence in results. In what follows, we will normally not comment further on the difference between bidding to buy and bidding to sell (Rothkopf & Harstad, 1994).

Many studies in the literature are concerned with the analysis of bidding behavior of contractors in auctions but not in tender contests (Skitmore, Pettitt, & McVinish, 2007), (Skitmore, 1991). In tenders, the contract is awarded depending on a number of technical and financial criteria. Auctions can be considered a simple type of tender as the contract is awarded using a single criterion: the economic one, (Skitmore, 2002, BOE, 2000) no matter how this criterion is implemented: English or Dutch auction, Open or Closed auction, Sealed-bid or Vickrey auction. The economic criterion most widely used in both processes (auctions and tender contests) is that of "the economically most advantageous bid" (Yeng-Horng; Yi-Kai & Sheng-Fe, 2006), the difference being that auctions rely exclusively on the economic criterion whereas tender contests use several technical and financial criteria. In tender contests, the economic criterion is weighted, just like any of the other criteria used in the process (Abudayyeh et. al, 2007).

Many recent studies that develop ranking models for the unbiased prioritization of bidders (Rothkopf & Harstad, 1994), (Abudayyeh et. al, 2007), (Rothkopf & Harstad, 1994), are based on multi-criteria decision analysis models (Li, Nie, & Chen, 2007) in detriment of the use of weighted financial factors. Even more recently some models facilitate and optimize the procedures of bidding by means of electronic systems (Manoliadis, Pantouvakis & Christodoulou, 2009), (Liao, Wang & Tserng, 2002).

However, the tool proposed later and the whole bid tender forecasting model (BTFM), that will be eventually explained, is not linked to any previous multi-criteria decision method, indeed it is *not* a multi-criteria tool. The aim of the BTFM is exclusively to represent the probability that each economic bid has of obtaining a particular score, position or, even, being considered risky by the owner. No other criteria will be involved but the economic one. In other words, whereas multi-criteria tools are usually applied to rank and weight several tender items (normally technical, administrative and economical items) but only as a whole, the BTFM will study the economic criterion in depth, trying to identify which range of potential bids have higher probabilities to win.

The criterion of economic scoring in public tender is a key issue since the score obtained will be further aggregated to the values obtained in the technical and financial criteria thus generating the final rank of bidders. In other words, the particular Economic Scoring Formula chosen by the owner to distribute the total amount of points, by which the economic part of the tender is being evaluated, is not trivial. This ranking will determine the most suitable bidders for contract award and, possibly, different Economic Scoring Formulas will lead to different bidder rankings.

The scores assigned to the technical factors and bid price of the proposals participating in a bidding process depend on the following two factors (Abudayyeh et. al, 2007):

- The relative weights (weighing) of the technical factors against the financial factors for each particular bid situation. It is not the same that in a tender the economic part involves only 35% (for instance) of the complete scoring factors, but that the economic element equals 100% (an auction, not a tender, as we have defined). Probably, the behavior of bidders will show different scales of economic aggressiveness.
- The mathematical model used to compare the bidders' bids for the technical and financial factors under consideration (Economic Scoring Formulas).

The main reason why multi-criteria decision models have been extensively used for ranking bidders is because subsequent sensitivity analyses have demonstrated that the final bidders' ranking greatly differs depending on the criteria and weights used in the evaluation process (Abudayyeh et. al, 2007), (Tsai, Wang & Lin, 2007). But, as was previously said, the proposed tool focuses on the study of economic probabilities getting a certain economic score, obviating other tender items.

## 4. Basic definitions

Public Administrations in different countries use different terms to refer to the same tender concepts. Additionally, some terms used in this paper do not match the standards of the Spanish Public Administration. Therefore, for clarity we will define some of the terms used in this work:

"*Economic Scoring Formula*" (ESF) is the set of mathematical expressions that are used to assign a certain numerical value to each bidder from his/her bid price expressed on a monetary-unit basis. ESF includes the mathematical operations that provide the score and the mathematical formula that determines which bids are considered abnormal or risky (*Abnormally Low Bids Criteria* (ALBC). ALBC has received much less attention in the literature than the analysis of contractor's bidding behaviour (Chao & Liou, 2007).

"*Scoring Parameter*"(SP). SP refers to the variables that allow ESF to be operational. They are calculated from the distribution of the bids participating in a tender contest.

"*Bidder Drop* (D). It is the discount or bid reduction in the initial price of a contract submitted by a given contractor for a particular contest. It is mathematically expressed as:

$$D_i = 1 - \frac{B_i}{A} \quad (1)$$

Where $D_i$ is the Drop (expressed in per-unit values) of bidder "i", $B_i$ is the Bid (expressed in monetary values) of bidder "i", and A is the initial Amount of money (in monetary values) of the Tender (generally set by the Public Administration).

ESF scores result from the input of the bidders' bids ($B_i$) (in monetary values) or through the transformation of bidders' bids into Drops ($D_i$) (in per-unit values). Both options have advantages, but for the comparison of bids in different bidding processes, with different initial bid amounts (A), it will be better to work with Drops ($D_i$) than with Monetary-based Bids ($B_i$).

## 5. Fieldwork

In order to have a number of representative ESF from different bidding processes for further analysis and SP ranking, a total of 120 real tender documents of Spanish Public Administrations and private companies were collected.

The dataset collected and analyzed is sufficiently representative as it comprises: Tender contests and Auctions, all kinds of public administrations (City Councils, local councils, semi-public entities, universities, ministries, and so on), a great variety of civil engineering works and services, representation of different geographical regions (including the islands) and a wide range of Tender Amounts. Although the sample only contains Spanish tender documents, the ESF and SP analyzed are common to those used in any country where the Administration sets an initial Tender Amount (A) against which candidates will underbid.

The specification of an initial Tender Amount A allows the use of Bid Drops as the Drop indicates a discount or bid reduction in the price relative to a fixed initial Amount A. The tool presented in this paper works well with both Tender Amounts and Bid Drops. The examples presented here have been calculated using Bid Drops expressed in per-unit values.

## 6. Scoring Parameters Classification

The Economic Scoring Formulas of the 120 contract documents have been calculated and the corresponding SP have been classified into two groups: Primary SP and Secondary SP.

The Primary SP are base line or reference parameters from which the Secondary SP are calculated.

The Primary SP are:

- *Mean Drop,* "$D_m$"; It is the mean value of the Bid Drops submitted by the total number of bidders admitted in a particular tender contest. The relation with the Mean Bid ($B_m$) in monetary values is: $B_m = (1 - D_m)\,A$
- *Maximum Drop,* "$D_{max}$"; it is the per-unit Drop corresponding to the Minimum Bid submitted by the bidders. Its relation with the Minimum Bid ($B_{min}$) in monetary value is: $B_{\min} = (1 - D_{\max})\,A$.
- *Minimum Drop,* "$D_{min}$"; it is the per-unit Drop corresponding to the Maximum Bid submitted by the bidders. Its relation with the Maximum Bid ($B_{max}$) in monetary value is: $B_{\max} = (1 - D_{\min})\,A$.
- *Drops' Standard Deviation,* (Drops' stdev), "σ"; in certain project-level-of-risk criteria it is typical to express bid rates on a percent basis relative to the Standard deviation values of the bids. Its relation with Bids' Standard Deviation (S) (Bids' stdev) in monetary value is: $S = \sigma \cdot A$.

The second group of SP consists of the Secondary SP. As mentioned above, they result from the calculation of one or more primary SP. The Secondary SP are:

- *Abnormal Drop* "$D_{abn}$" is the Drop Threshold value; bids below this threshold value will be considered abnormal or risky. The Abnormal Drop is calculated with a formula that includes some primary SP such as $D_m$ (for example, a certain percentage value lower than the Mean Drop). Its relation with Abnormal Bid ($B_{abn}$) in monetary value is: $B_{abn} = (1 - D_{abn})\,A$;

when $D_{abn}$ is calculated as a distance from average T (in per-unit values) relative to $D_m$, the expression is: $D_{abn} = 1-(1-T)(1-D_m)$.

- *Corrected Mean Drop*, "$D_{mC}$"; it consists of an adapted $D_m$, usually obtained after rejecting extremely high/low bids or bids included within a certain range of margin, e.g. $D_m \pm \sigma$.
- *Allowable Maximum Drop*, "$D_{max}$*"; is the maximum non-risk or abnormal bid drop.
- *Complex Parameters*. ESF may require the use of parameters calculated from one or several primary SP with different mathematical criteria. Through a single mathematical expression that operates with "Absolute Values" over certain primary SP, Complex Parameters allow the generation of a new curve that represents very different scoring intervals. It is used for very unusual ESF and SP.

Primary and Secondary SP are combined mathematically to generate specific ESF for each particular bid situation and should be clearly specified in the contract conditions of the tender.

## 7. The iso-Score Curve Graph

The iso-Score Curve "iSC" is defined as the geometrical region of points associated with the bids submitted by a bidder and scored with the same number of points according to a known ESF.

An iso-Score Curve Graph "iSCG" is a 2D graphical representation with the following features:

- It represents an ESF Score Parameter on axis X
- It represents Bidders' Drop ($D_i$) on axis Y
- It represents the iso-score curves of the ESF at predefined scoring intervals ($S_i$)

Iso-score curves can represent score values; for example, for an ESF that distributes up to 50 points among the bidders, we can obtain 50-point, 45-point, 40-point curves … up to the 0-point curve. Additionally, iso-score curves can also represent a value-scale in per-unit values; in our example, the 1-iso-score curve corresponds to the 50-point curve, the 0.90-iso-score curve to the 45-point curve, the 0.80-iso-score curve to the 40-point curve, and so on.

The use of per-unit curves is much more advisable as their value is independent of the weighing of the financial factors relative to the technical factors.

The procedure to generate iso-Score Curves from the ESF is as follows:

1. Express mathematically the Economic Scoring formula.
2. Convert the ESF (when expressed in monetary units) into Drops (with parameters expressed in per-unit values).
3. Express the ESF in terms of a single Score Parameter, SP, (when the ESF contains more than one SP) for the 2D representation of the parameters.
4. Calculate variable Di (Bidders' Drop) from the expression of the ESF obtained in the previous step.
5. Represent the different iSC graphically for the required and/or selected score values ($S_i$).

Following, this procedure is applied to three case studies for the generation of iSCGs. We have developed three case studies so as to cover the most typical ESF found in Spanish tender contests, in terms of SP and abnormal or project-risk criteria.

Based on the information provided by the representation of the iSCG of these three ESF, the iSCG of other less typical ESF can be obtained.

The procedure to obtain these iSCG follows the 5 steps described above. In order to simplify the text, the equations for each step will be included in the appendix, starting from the second step.

### 7.1 Mathematical expression of the ESF

The mathematical expression of the ESF should be specified by the Public Administration or the owner in the contract documents of the tender; however sometimes it is expressed in linguistic terms rather than numerically. In such a case, the first step will be to express the ESF mathematically.

*Case 1:*

The ESF is represented by the following mathematical expressions:

$$S_i = 50\left(1 - \frac{B_i - B_{\min}}{B_{\min}}\right) \quad \text{and} \quad B_{abn} = (1-T)\, B_m \qquad \text{(A1.1)}$$

Where:

$S_i$ = Score of bidder “i” . Assume that, according to the contract conditions of the tender contest, bidders can get scores between 0 and 50 points ($0 \leq S_i \leq 50$). For the expression of the score in per-unit values, value 50 will be replaced by 1.

$B_i$ : Bid price in monetary value of bidder “i” for the execution of the contract

$B_{min}$ : The lowest allowable bid (but not abnormally low bid), i.e. $B_{min}>B_{abn}$, proposed by the bidders.

$B_{abn}$ : Bid Price in monetary value below which the bid is considered abnormally low.

T: Abnormally High Drop Threshold. For the case study under consideration the documents of the tender contest set a value of 10% (0.10).

$B_m$: Mean value of the bids in monetary value.

*Case 2:*

$$S_i = 35\frac{A - B_i}{A - B_{\min}} \quad \text{and} \quad B_{abn} = B_m - 2\,S \qquad \text{(A2.1)}$$

Where:

A is the initial contract price (tender Amount) in monetary value (set by the Administration).

$S_i$ : Score of bidder “i” . Assume that, according to the tender conditions, bidders can get scores between 0 and 35 points ($0 \leq S_i \leq 35$). For the expression of the score in per-unit values, value 35 will be replaced by 1.

S : Standard deviation of the bids in monetary value.

$B_i$, $B_{min}$, $B_{abn}$ and $B_m$ are the same parameters as those used in Case 1.

*Case 3:*

$$S_i = 40 - 10\frac{B_i - B_{\min}}{B_m - B_{\min}} \quad \text{and} \quad B_{abn} = (1-T)\, A \qquad \text{(A3.1)}$$

Where all variables have been described in the case studies above. Let $S_i$ (according to some hypothetical tender conditions) be between 0 and 40 points ($0 \leq S_i \leq 40$). For the expression of the score in per-unit values, value 40 will be replaced by 1 and value 10 by 0.25.

Assume that in this example the tender document sets the Abnormally High Drop Threshold (T) to 30% (0.30).

### 7.2 Transformation of the ESF into Drops

This step is required when ESF is not expressed in per-unit Drops but in monetary values. The necessary expressions for the transformation of ESF into Drops are:

$$B_{\min} = (1 - D_{\max})\,A\,; \quad B_{\max} = (1 - D_{\min})\,A\,; \quad B_m = (1 - D_m)\,A\,; \qquad (2, 3, 4)$$

$$B_{abn} = (1 - D_{abn})\,A\,; \quad S = \sigma \cdot A \qquad (5, 6)$$

Basically it comes down to a matter of changing $B_x$ variables for $D_x$ variables, with *x* equals *m*, *min*, *max* or *abn*.

The expressions of the three cases in per-unit Drops, assuming that $S_i$ is also expressed in per-unit values, are shown in the appendix for: Case 1 (equation A1.2), Case 2 (equation A2.2) and Case 3 (equation A3.2).

### 7.3 Expressing ESF in terms of a single Scoring Parameter

Taking into account that the iSCG puts in the X-axis an SP, the ESF must be expressed in function of a single SP, otherwise it is impossible to represent a 2D graph.

Any parameter can be used to express ESF, but it is better to use a parameter already expressed mathematically (e.g. $D_m$ and/or $D_{max}$).

For the transformation of a multi-parameter ESF into a single-parameter ESF it is necessary to know the following proposed primary relations between scoring parameters:

$$D_{\max} = D_m{}^{a}\,; \quad D_{\min} = D_m{}^{b}\,; \quad \sigma = K\,(D_{\max} - D_{\min}) \quad (7, 8, 9)$$

These relations were obtained from the analysis of the 120 contract documents of Spanish Public Administrations and Private Companies. Note that $D_m$, $D_{min}$ and $D_{max}$ are correlation curves that cross points (0,0) and (1,1), whereas the fitting curve of σ always crosses (0,0) and (1,0).

In addition, the correlation between variables depends on random coefficients (a, b and K). These coefficients are obtained from any recent record data belonging to the same Administration and using the same ESF.

After the identification of the correlation curves that best correlate the scoring parameters, the expressions of the case studies are shown in the appendix: Case 1 (equations A1.3a and A1.3b), Case 2 (equations A2.3a and A2.3b) and Case 3 (equations A3.3a and A3.3b).

Note that a, b, K and T are coefficients of known value whose numerical determination is necessary for the representation of the iso-Score Curves.

### 7.4 Calculate variable $D_i$ from the ESF

Starting from the expressions calculated in the previous step, it is a matter of working out the value of Di and Dabn. The following results are obtained for each case study in the appendix: Case 1 (equations A1.4a and A1.4b), Case 2 (equations A2.4a and A2.4b) and Case 3 (equations A3.4a and A3.4b).

When seeing step 4’s equations note that it was not necessary to perform additional transformations over the expressions of $D_{abn}$ since $D_{abn}$ is actually a curve ready to be represented once the values of $D_m$ or $D_{max}$ are known.

### 7.5 Plotting the iso-Score Curves

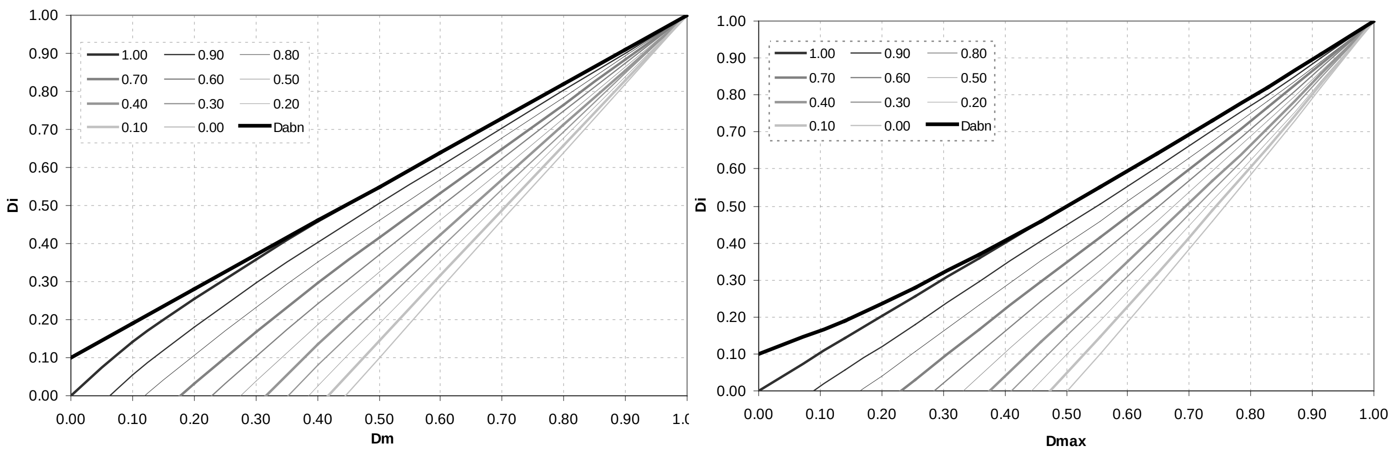
Finally, variable Si has to be equalled to the values whose score is to be represented. In the cases under analysis, the following values were selected: 1, 0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1 and 0.

To facilitate the obtaining of numerical values the following generic values were assigned: a=0.85, b=1.50 and K=0.30 (the numerical values should be obtained from the analysis of the databases of each public administration for a given ESF, as aforementioned) and the values of T mentioned above (T=0.10 in Case 1 and T=0.30 in Case 3).

From the data and representation of these 11 curves plus the $D_{abn}$ curve for each case under analysis, we obtain the following graphs whose numerical data are shown in the appendix: Case 1 (Table 1), Case 2 (Table 2) and Case 3 (Table 3).

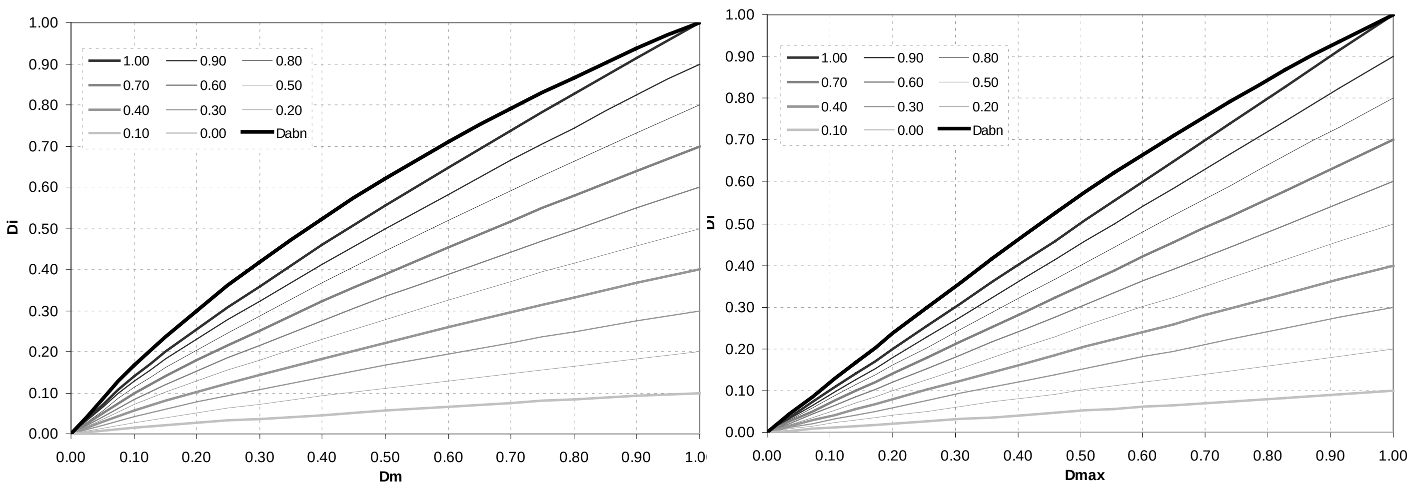
_Case 1:_

**Figure 1: iso-Score Curve Graph Case 1 for the Mean Drop ($D_m$) and Maximum Drop ($D_{max}$)**



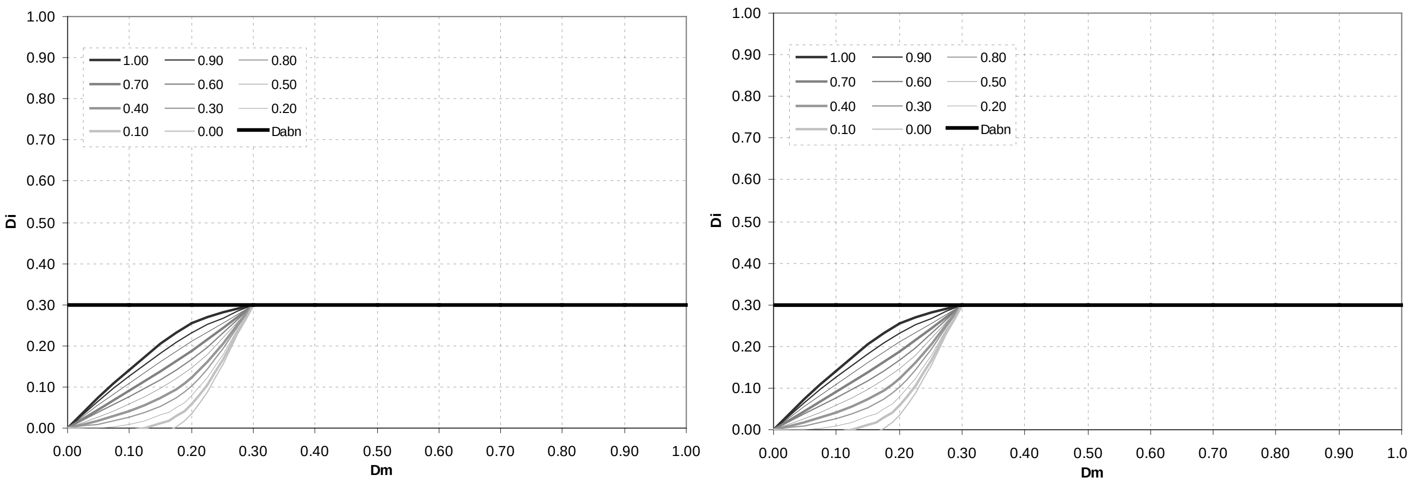

_Case 2:_

**Figure 2: iso-Score Curve Graph of Case 2 for the Mean Drop (Dm) and Maximum Drop (Dmax)**



*Case 3:*

**Figure 3: iso-Score Curve Graph of Case 3 for the Mean Drop ($D_m$) and Maximum Drop ($D_{max}$)**




## 7.6 Interpretation of the iSCG

The iSCG allows the visual observation of the distribution of points for a given ESF in a simple way. The analysis of the graphs obtained in the examples reveals that:

*Case 1:*

Competitive bids lie within the range [$D_m$, $D_{max}$-0,05]; within this range the score values will always be higher than 90%.

It seems difficult to be eliminated by the criterion of abnormally low bid for $D_m$ intervals higher than 0.35 (which corresponds to relatively higher $D_i$ bids).

*Case 2:*

Zero Drop bids should not be presented as the bidder would receive 0 points; additionally the total score significantly drops as the distance from $D_{max}$ increases.

In the $D_m$ range of 0.30-0.70 it seems difficult to surpass the Abnormally Low Bid Threshold, which corresponds to the $D_{max}$ range of 0.36-0.74 (a wide range).

It is convenient to set the bid price within the range $0.9 \cdot D_{max}$ and $1.2 \cdot D_{max}$, as within this range there are high expectations of being well rated and low probability of being abnormally low.

*Case 3:*

As in the case above, Zero Drop bids should not be presented to avoid zero scores, and in this case, $D_i$ should never exceed 0.30.

The probability of getting very low scores for bids below $D_{max}$ is very high and the risk to exceed the abnormally low bid threshold for drops lower than 0.30 is zero, so that bidders should set their $D_i$ close to 0.30 even if substantially sacrificing their estimated profit.

Bidders should try to surpass the $D_{max}$, so that the bid should lie between $D_{max}$ and T (equal to 0.30).

## 8. Conclusions

Since it should be kept in mind that sometimes understanding how the Economic Scoring Formula (ESF) in a tender operates is not evident from direct observation of the mathematical expression, iSCGs allow the visual observation of any financial scoring criterion in a simple and graphical form.

Once the decision maker is trained on its use, the method allows finding aspects of the ESF that can help bidders to set their bids within more advantageous bid margins. On the other hand, also Public Administration might predict bids that are going to receive and integrate them in its own information systems or even decide which ESF should be more suitable for its own tender purposes or aims.

An additional advantage of the use of iSC graphs is that they allow the representation of tender datasets and greatly help to adjust the regression curves (to determine the values of coefficients a, b and K among others) that will allow a bidder to predict the bids of his/her competitors in future bidding processes. Related to the previous thing, the technologies of the data mining are very useful for the extraction of information of biddings (Cao, Wang & Li, 2002).

### Appendix

Equations of iSCGs' Calculation steps for the three cases:

<u>Case 1</u>

1) $S_i = 50\left(1 - \frac{B_i - B_{\min}}{B_{\min}}\right)$ and $B_{abn} = (1 - T)\,B_m$ (A1.1)

2) $S_i = 1 - \frac{D_{\max} - D_i}{1 - D_{\max}}$ and $D_{abn} = 1 - (1 - T)(1 - D_m)$ (A1.2)

3) $S_i = f(D_{\max}) = 1 - \frac{D_{\max} - D_i}{1 - D_{\max}}$ and $D_{abn} = f(D_{\max}) = 1 - (1 - T)\left(1 - D_m^{\frac{1}{a}}\right)$ (A1.3a)

$S_i = f(D_m) = 1 - \frac{D_m^{a} - D_i}{1 - D_m^{a}}$ and $D_{abn} = f(D_m) = 1 - (1 - T)(1 - D_m)$ (A1.3b)

4) $D_i = f(D_{\max}) = D_{\max} - (1 - S_i)(1 - D_{\max})$ and $D_{abn} = f(D_{\max}) = 1 - (1 - T)\left(1 - D_m^{\frac{1}{a}}\right)$ (A1.4a)

$D_i = f(D_m) = D_m^{a} - (1 - S_i)\left(1 - D_m^{a}\right)$ and $D_{abn} = f(D_m) = 1 - (1 - T)(1 - D_m)$ (A1.4b)

<u>Case 2</u>

1) $S_i = 35\frac{A - B_i}{A - B_{\min}}$ and $B_{abn} = B_m - 2\,S$ (A2.1)

2) $S_i = \frac{D_i}{D_{\max}}$ and $D_{abn} = D_m + 2\sigma$ (A2.2)

3) $S_i = f(D_{\max}) = \frac{D_i}{D_{\max}}$ and $D_{abn} = f(D_{\max}) = D_m^{\frac{1}{a}} + 2\,K\left(D_{\max} - D_{\max}^{\frac{b}{a}}\right)$ (A2.3a)

$S_i = f(D_m) = \frac{D_i}{D_m^{\,a}}$ and $D_{abn} = f(D_m) = D_m + 2\,K\left(D_m^{\,a} - D_{\max}^{\,b}\right)$ (A2.3b)

4) $D_i = f(D_{\max}) = S_i \cdot D_{\max}$ and $D_{abn} = f(D_{\max}) = D_m^{\frac{1}{a}} + 2\,K\left(D_{\max} - D_{\max}^{\frac{b}{a}}\right)$ (A2.4a)

$D_i = f(D_m) = S_i \cdot D_m^{\,a}$ and $D_{abn} = f(D_m) = D_m + 2\,K\left(D_m^{\,a} - D_{\max}^{\,b}\right)$ (A2.4b)

**Case 3**

1) $S_i = 40 - 10\frac{B_i - B_{\min}}{B_m - B_{\min}}$ and $B_{abn} = (1 - T)\,A$ (A3.1)

2) $S_i = 1 - 0.25\frac{D_{\max} - D_i}{D_{\max} - D_m}$ and $D_{abn} = T$ (A3.2)

3) $S_i = f(D_{\max}) = 1 - 0.25\frac{D_{\max} - D_i}{D_{\max} - D_{\max}^{\frac{1}{a}}}$ and $D_{abn} = f(D_{\max}) = T$ (A3.3a)

$S_i = f(D_m) = 1 - 0.25\frac{D_m^{\,a} - D_i}{D_m^{\,a} - D_m}$ and $D_{abn} = f(D_m) = T$ (A3.3b)

4) $D_i = f(D_{\max}) = D_{\max} - 4\,(1 - S_i)\left(D_{\max} - D_{\max}^{\frac{1}{a}}\right)$ and $D_{abn} = f(D_{\max}) = T$ (A3.4a)

$D_i = f(D_m) = D_m^{\,a} - 4\,(1 - S_i)\left(D_m^{\,a} - D_m\right)$ and $D_{abn} = f(D_m) = T$ (A3.4b)

## References

Abudayyeh, O. Zidan, S.J. Yehia, S. and Randolph, D. “Hybrid Prequalification-Based, Innovative Contracting Model Using AHP”. Journal of Management in Engineering. **23 (**2) (2007) 88-96.

Cao, Y. Wang, S. & Li, H. “Automatic recognition of tables in construction tender documents” Automation in Construction, **11** (5) (2002) 573-584.

Carr R. I. “General bidding model” Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, **108** (CO4) (1982) 639-50.

Chao, L. & Liou C. “Risk-minimizing approach to bid-cutting limit determination”. Construction Management and Economics. **25** (8) (2007) 835-843.

Friedman “A competitive bidding strategy” Operations Research **1** (4) (1956) 104-12.

Gates M. “Bidding strategies and probabilities” Journal of the Construction Division, Proceedings of the American Society of Civil Engineers, **93** (CO1) (1967) 75-107.

Liao, T.S.. Wang, M.T &. Tserng, H.P “A framework of electronic tendering for government procurement: a lesson learned in Taiwan” Automation in Construction, **11** (6) (2002) 731-742

Manoliadis, O. G.. Pantouvakis J. P &. Christodoulou S. E “Improving qualifications-based selection by use of the fuzzy Delphi method” Construction Management and Economics, **27** (4) (2009) 373-384

McCaffer R. & Pettitt A. N. “Distribution of bids for buildings and road contracts” Operational Research Quarterly, **27** (4i) (1976) 835-43.

Mitchell M. S. “The probability of being the lowest bidder” Applied Statistics **2** (2) (1977) 191-4.

Pastor-Ferrando J. P., Aragonés-Beltrán, P. Hospitaler-Pérez A. and García-Melón M. “An ANP- and AHP-based approach for weighting criteria in public works bidding” Journal of the Operational Research Society **61** (special issue) (2010) 905-916

Pim J. C. “Competitive tendering and bidding strategy” National Builder **55** (11) (1974) 541-545.

Rothkopf M.H. & Harstad R.M. “Modeling Competitive Bidding: A Critical Essay”. Management Science. **40** (3) (1994) 364-384.

Skitmore, R.M. “The probability of tendering the lowest bid in sealed auctions: an empirical analysis of construction data”. Journal of the Operational Research Society. **53** (1) (2002) 47-56.

Stark R. M. & Rothkopf M. H. “Competitive bidding: A comprehensive bibliography.” Journal of the Operational Research **27** (2) (1979) 364–390.

Skitmore R.M, Pettitt, A.N and McVinish, R. “Gates' Bidding Model”. Journal of Construction Engineering and Management. **133** (11) (2007) 855-863.

Skitmore R.M. “The contract bidder homogeneity assumption: an empirical analysis.” Construction Management and Economics. **9** (5) (1991) 403-429.

Real Decreto Legislativo 2/2000, de 16 de junio, por el que se aprueba el texto refundido de la Ley de Contratos de las Administraciones Públicas. *Boletín Oficial del Estado* **148** (2000).

Yeng-Horng P. Yi-Kai J. & Sheng-Fen Ch. “Exploring the Bidding Situation for Economically Most Advantageous Tender Projects Using a Bidding Game”. Journal of Construction Engineering and Management. **132** (10) (2006) 1037-1042

**Correspondencia** (Para más información contacte con):

Pablo Ballesteros Pérez
Depuración de Aguas del Mediterráneo S.L. (DAM)
Phone: + 34 902 881 510 Ext. 366
Fax: + + 34 963 531 225
E-mail: pablo.ballesteros@dam-aguas.es
URL: http://www.dam-aguas.es