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Monitoring Public Procurement Using a Fuzzy Logic System

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Abstract

The problem of monitoring public procurement is a vital issue, especially in the European Union (EU), where the free movement of goods is finally established by the "Single European Act". A monitoring system that could be applied after public procurement contracts have been awarded, would examine and identify the existence both, of corruption and of "buy national" policies and practices (i.e. policies favouring domestic suppliers). In this article, the use of a fuzzy logic system as a monitoring mechanism for public procurement is proposed. Using this system, national or EU surveillance authorities can sort the contractors in a series of categories, identifying the degree of their efficiency. The design and implementation of the proposed fuzzy logic system is presented, followed by demonstrative examples of its operation. This system, which applies mainly to goods and services, can also be used as a decision support system at the stage of the selection process, assisting the choice of the best contractor.

Keywords: Public procurement; Monitoring; Fuzzy logic systems; Selection criteria

Introduction

"Buy national" policies, through discrimination practices among bidders, aim at protecting domestic production and hence employment [1-3]. These practices still remain active in EU Commission of the EU [4,5]. In fact, the abolition of "buy national" rules necessitates a long and painful procedure because, in general, governments are reluctant to implement the "equal treatment" principle in their public procurement practices [6]. Consequently, "buy national" policies persist, despite either the 'Single European Act' provisions for market openness (EC Directives 93/36, 93/37, 93/38 and the new series of 2004/18 and 2014/24) or the 'Tokyo' and 'Uruguay' Rounds Trade Agreements (such as the Government Procurement Agreements - GPA).

Why does this happen? Because the selection and award criteria of any call for tender tend to establish in many cases, a process in favour of a domestic producer, who is currently a "bad" supplier or more precisely an inefficient producer. The above mentioned criteria can consequently operate against all efficient bidders. The role of the awarding authority remains crucial in that context.

The only surveillance mechanism in this field is based on legal means and more precisely on the existing recourse process. However, a surveillance mechanism, based on analytical tools, which aims at measuring the efficiency of any contractor, can be more operational. For this reason, a series of indicators can offer better results in the frame of this proposed mechanism. A monitoring authority (e.g. the Commission of the EU or a national authority), using the suggested method, can identify if a public sector supplier (the contractor) is also a "good" producer in terms of production efficiency (e.g. economies of scale, increased productivity, innovative efforts), which points out that it is capable to fulfill the procurement contract. The suggested method, operating out of the selection and award public procurement criteria, focuses on the contractor and not on all bidders. Thus, it is not a selection mechanism, according to the existing rules, because there is not any provision for that, following the existing EU Directives.

Analytically, EU Directives on public procurement, that refer to the selection criteria (i.e. the financial-economic standing and technical capacity) focus on absolute values (e.g. minimum own funds, statesman of firm's overall annual turnover, manpower and managerial staff). For the sake of the present study, the following major changes would be required to make the system legally acceptable: Relative values have to replace the existing ones [7]. However, this approach requires the revision of the Article 48 of EU Directive 2004/18, about technical and professional capacity (or Articles 22 and 23 of previous EC Directive 93/36 about the financial-economic standing and technical capacity, for supplies as for example).

Taking into account the above mentioned approach, the suggested method is activated at the end of the award process. It is an ex post tactic to that process analysis. It interferes more precisely, when the contract is signed. It aims analytically to point out how the awarding authority operates in practice. It is consequently a surveillance mechanism, where two parties are involved: The monitoring authority and the awarding national authority.

In the next section, the existence of "buy national" policies is discussed and the lack of monitoring public procurement is presented. Section 3 describes the stages of public procurement processes and presents the proposed surveillance mechanism. The indicators and criteria that determine a contractor as a "good" contractor are discussed in section 4. The next two sections refer to the design and implementation of the fuzzy logic system that can monitor public procurement. The article ends with a section presenting the conclusions of this work, giving indications of future work.

"Buy national" Policies and Lack of Monitoring Public Procurement

Public procurement "buy national" policies have been one of the most significant barriers to trade. Governments using discriminatory methods against foreign bidders aim at preserving domestic production via technical requirements, financial incentives and price mechanism [8] despite substantial loss of the budget resources [9,10] and the welfare losses as well. "Buy national' policies give opportunities for production modernization. They are also considered as a main protection mechanism for medium size enterprises [11,12]. They can influence market structure and they tend to underpin regional policies.

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Although "buy national" policies are neither directly observable nor codified in written rules, empirical research shows substantial interference of their instruments on the pattern of domestic output and specialization [13,14]. They show more precisely that they can reduce imports and influence international specialization, especially in the manufacturing sectors. However, the influence of "buy national" policies on output varies; they are more significant in certain sectors. Their impact depends on the characteristics of the market structure and the size of the demand. Thus, "buy national" is likely to influence international specialization, more in sectors characterized by increasing returns to scale than in those characterized by constant returns to scale [15,16]. Consequently, it affects high tech and traditional industries in different ways. Therefore, under specific conditions, a country with relatively large extent of home biased government expenditure tends to host a relatively high specialization in products involved in public procurement.

In order to become more efficient the domestic production, governments should simultaneously stimulate competition and hence minimize expected procurement costs in a frame of a medium term public procurement strategy [17,18]. In that context, a competitive domestic supplier can operate efficiently against the foreign bidders under free trade. If this happens, we expect a positive impact on the firm's production and trade performance (expressed as for example by export performance, production internationalization, labor productivity and specialization) regarding its sales, towards the public sector [19].

"Buy national" policies form a range of either defensive practices in favor of less competitive domestic suppliers, or offensive techniques, which aim at increasing their efficiency in a medium or long term vision. On the other hand an open public procurement market prevents the protection of less efficient domestic suppliers. However "buy national" policy may apply through a hidden protection expressed by the selection and award criteria of any call for tender. A recourse process could cure the market from such practices. Nevertheless, the recourse process is not currently operational in all cases (e.g. in the case of oligopolistic competition, which is the main source of games theory.) In contrast, a surveillance mechanism based on suppliers' market profile, can provide more accurate results in this matter.

One of the most researched areas in purchasing and supply management is that of supplier selection. Various conceptual or empirical methodologies regarding this topic have been developed [20-22]. The complexity of the supplier selection problem and the uncertain qualitative factors that are involved in this problem led to the development of techniques that cope with fuzziness by applying fuzzy logic methods [23-26]. These methods can handle and manipulate fuzziness in a manner that leads to meaningful results. Besides that, over the last years, electronic procurement has gained popularity [27] and e-procurement systems concerning public sector have been proposed [28].

An awarding authority works efficiently, if the selection and awarding criteria, which have been chosen and inserted by them to any call for tender, lead finally to a "good" contractor which is a "good" producer as well. In contrast, many questions can be arisen due to either an oligopolistic structure of the public procurement market or to the hidden protection or to the corruption process.

In general, a monitoring authority can establish a surveillance mechanism, based on a series of indicators that depict the performance of the contractor. This mechanism may overcome the anti-market practices of suppliers' behavior and of the contracting authorities. The monitoring authority needs to ask the following question: How can a badly performed supplier (in terms of poor productivity, low market penetration, weak export potential and specialization, etc.) intensively participate to public procurement under free trade rules, without the assistance of any "buy national" techniques?

There is a lack of research concerning the monitoring of procurement after the selection of the supplier/contractor, which is important especially in the European Union where "buy national" policies might be applied by the Member States of EU. In this study, a fuzzy logic system was built that monitors public procurement, in order to examine to what extent the selected suppliers might be involved in any awarded contract, or alternatively –especially for EU– to what extent "buy national" policies are applied in practice.

The fuzzy logic system that is described in section 5, examines the degree to which a contractor of any public procurement is "good" or "bad" regarding the supply of a Product (i), in terms of efficiency. It can identify if hidden "buy national" policies still exist under free trade rules. Meanwhile, we cannot exclude cases, where inexpert drafting of selection and award criteria or any other mundane reasons, can favor occasionally a non-competitive domestic supplier. We may consider it as an exceptional case. However, in the case where these practices always lead to a domestic supplier, then we can consider it as part of "buy national" techniques and not occasional events.

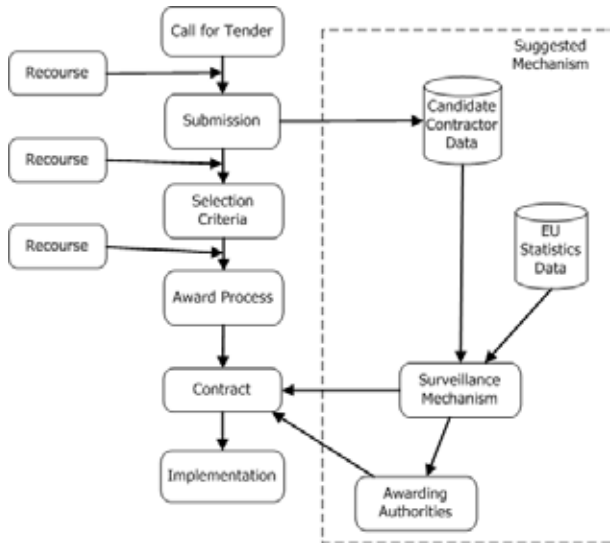
Stages of Public Procurement Process and the Proposed Surveillance Mechanism

The public procurement process has a number of stages. The process starts with the call for tender from a public authority (Figure 1), giving the opportunity to every candidate contractor to submit his proposal. The next stage, called selection criteria, has to do with the examination of the contractor. A set of criteria, which depict the economic, financial and technical profile of the supplier, are examined in order to determine whether the candidate is capable to sign the contract. The selection criteria can be divided into strong criteria ("must have" criteria) and weak criteria ("nice to have" criteria). In this stage, the evaluation process refers only to the candidate, not to the product he offers. The task of evaluating the offering product(s) is that of the next stage, called award process. After thorough evaluation of the product(s), the awarded candidate is announced and can proceed to the contract. The surveillance mechanism that is proposed in this article is applied in this stage (Figure 1). This mechanism needs: a) data collected during the submission of the candidate contractor and b) data concerning EU statistics of various business sectors. Through this mechanism, a surveillance authority aims at checking whether the contractor is a "good" or a "bad" supplier for the supply of Product (i) that the contract refers to. On the other hand, it also certifies the proper operation of the awarding authority. Consequently, this mechanism can point out the "quality" of the selection criteria.

Indicators and Criteria Determining a "Good" Contractor

The key point in order to correctly characterize a contractor as "good" is to identify the right indicators and criteria that distinguish the "good" from the "bad" contractor.

The first attempt which has tried to insert a surveillance mechanism via a series of indicators took place during the beginning of the 90s, in the frame of the European Commission (Commission of the EC, 1994). However, due to the luck of data on supplier's level, the methodology has been based on sectoral level. Three indicators have been used for



More about the selection criteria and an alternative, compatible to the suggested mechanism can be found in (Mardas and Triantafyllou 1995)

Figure 1: Stages of Public Procurement.

this goal, which are a) the coverage rate ratio (i.e. export/import ratio), b) Balassa specialization index [29] and c) the intra-industry trade indicator of Grulel and Lloyd [30]. The choice of the above mentioned indicators can be explained by the fact that data were available on member-states basis, and not on contractor's level.

This problem still exist in EU, since data on contractor's level are missing, which makes the construction of the necessary indicators for a surveillance mechanism, not possible. This justifies the lack of the empirical investigation on contractor level. However, the existing empirical research on sectoral level –see below– provides interesting results in favor of our proposed methodology.

The appropriate data on contractor's level can be collect using the following method. The supplier can provide public authorities with all appropriate data on firm and on product level, that are needed for the sake of the surveillance mechanism under examination, by the signature of the contract.

As far as the existing empirical research is concerned, following the above mentioned attempt on behalf of the European Commission, a first series of studies on 12 member-states of the EU has been made (Commission of the EC, 1994). A second series of studies followed, that was based on the same methodology and concerned all the countries of the former Easter and Central Europe, which were part of "Europe Agreements" (e.g. preparatory agreements in the horizon of their future entry to the EU) [31].

A study of NERA [32] in September 2004, proposed a similar methodology to the one we propose in this paper. However, that study tried to screen private market problems. Our research uses some key indicators suggested by the above mentioned study that concerns innovation, labor productivity and extent of production internationalization.

A theoretical attempt which aimed to point out the suitability of the method under examination, took place at the beginning of the mid-1990. Besides, a theoretical explanation of a surveillance mechanism, which can depict the extent of discrimination among suppliers, attracted the attention of a series of studies [33].

A series of indicators that should be examined by a monitoring system are:

A) Indicators concerning the business structure of the product dealing with public procurement (supply)

Indicator #1: Sales to private sector/Sales to public sector

Indicator #2: Exports/Total sales

B) Indicators concerning the extent of the internationalization of the product dealing with public procurement (supply)

Indicator #3: Specialization index

Indicator #4: Imports (intermediate goods)/Total sales C)

C) Indicators concerning the technological innovation efforts of the contractor

Indicator #5: Number of technicians/Total number of employees

Indicator #6: Number of scientific personnel/Total number of employees

Indicator #7: R&D expenditures/Total sales

D) Indicators concerning the contractor's productivity

Indicator #8: Investments in equipment/Total sales

Indicator #9: Investments in buildings/Total investments

Indicator #10: Sales/Number of employees.

Indicator #1 points out the contractor's extent of market penetration on product level (i.e. on the supply). If a producer is efficient, then it sells the product under consideration, either to the private or to public sector. A high ratio depicts its increased competitive position due to its capability to capture the private markets. This also explains its capability to penetrate to public procurement markets without any preferential treatment on behalf of the awarding authority. This ratio is an extension of Atkins' approach regarding public market openness, which has been developed in the frame of the study, entitled the "Cost of Non Europe" [34].

Indicator #2, #3 and #4 depict the extent of production internationalization on product level again. The production internationalization process leads to economies of scale and hence to cost reduction efforts. The two first ratios have been used in the context of the European Commission's study related to the surveillance mechanism of public procurement. (Commission of the EC, 1994). They are traditional indicators which can illustrate the extent of the comparative advantage.

More precisely, regarding indicator #3 on specialisation index, we propose Balassa index, which combines data on product level with data on country level.

$$R_j = \frac{X_{ij}}{\sum X_{.j}} \Big/ \frac{\sum X_{ic}}{\sum X_{.c}} \quad (1)$$

Where:

X_{ij} = Exports of product (supply) (i) of country (j)

$\sum X_{.j}$ =Total exports (.) of country (j)

$\sum X_{ic}$ =EU (c) exports of product (i)

$\sum X_{.c}$ =Total exports (.) of the EU (c)

The third ratio describes the extent of production internationalisation process. The above mentioned study of the Commission of the EC, has used an alternative expression of the internationalisation process, expressed by a ratio of Grubel and Lloyd on intra-industry trade. All these ratios constitute analytical tools, which are used in international trade models.

Indicators #5, #6 and #7 points out the 'technological gap' on producer (supplier) level, [35] i.e. its dynamic comparative advantage via innovation efforts. These ratios have been used in the frame of empirical research launched by number of trade specialist, who aimed to insert proof about dynamic comparative advantage [36,37]. The three indicators under consideration tend to distinguish goods in two major groups: the high Research-Development (R-D) products and the low tech standardized products. However they do not provoke any trouble to the surveillance system, because of their 'horizontal' meaning. In more details, each call for tender concern the same type of products –either low, medium or high technology ones. Thus, we do not expect for example, the procurement regarding a high tech computer to compete to another procurement regarding a medium or low class computer.

Indicators #8, #9 and #10 consist of an expression of supplier's productivity (see also NERA study, 2004). Finally all relative values, as shown by the proposed indicators, favour a small or medium size dynamic firm against a big one. In contrast, the use of absolute values (e.g. number of, researchers, technicians etc) favours big firms.

The above mentioned indicators are used either on their own or in groups to facilitate researches that mainly concern international trade analysis, market openness or market investigation on firm or sectoral level. However, the use of all of them in the frame of a surveillance public procurement mechanism reflects the originality of the present study.

Each of the above ten indicators corresponds to a certain criterion that any should satisfy in order to be classified as "good" for the supply of a Product (i). The analysis which follows assimilates the term contactor with a producer and not with whosale firms. The criteria are formed by stating that all the above indicators of the contractor, in the same business sector (e.g. telecommunications), should have values equal or better than the average value of the same indicator in the EU. For example, to examine if a contractor is "good" in supplying Product (i) (e.g. telecommunication equipments), a table like Table 1 should be created.

In Table 1, the contractor is characterized as "good" for the supply of Product (i), because all criteria are satisfied. In general, a contractor can be characterized as "bad" when at least one criterion is not satisfied. Table 2 provides the characterization of the contractor, depending on the total number of criteria satisfied.

The above method has the disadvantage that all contractors are divided into two categories and the degree to which a contractor fails or satisfies the criteria is not measured. This means that two contractors might be characterized as equally "bad", even though the first one has very low indexes compared to the EU level and the second one has marginally failed to satisfy some criteria, having indexes very close to those of the EU.

A clear improvement to the above would be to fuzzify the criteria thresholds and present the degree each criterion is satisfied. This can be achieved through the development of a fuzzy logic system [38,39]. Fuzzy Logic Systems are capable to represent the fuzziness that exists endogenously in many problems. Their inference capabilities are significant because they are able to present even the fuzziness of real world problems. Their main achievement is that instead of just giving a result, they give both a result and a degree of the certainty that this result is valid. For example, although a common decision support system would give a result that e.g. company X is efficient, a fuzzy logic system would give as result that company X belongs to the set of efficient companies with a degree e.g. of 80%. This is very important e.g. in cases that someone wants to sort companies based on their efficiency.

Design of the Fuzzy Logic System

In order to improve the method for characterizing a contractor as "good" or "bad", as described in the previous section, two design choices have to be made:

Define the weight for each criterion

Criteria of Table 1, do not have the same importance when are used in order to characterize a contractor "good" or "bad". Some criteria are considered more important and consequently bigger weights should be assigned to them. After applying knowledge acquisition techniques [40] to an expert in the EU public procurements, and after taking into account a series of call for tender practices launched by member-states public authorities, the weights for the 10 criteria where defined, normalized and they are presented in Table 3. However, the choice of the weights depends on the policy makers or on the officials, competent

No	Indicators	Contractor's Index	Index at the EU level	Criteria Threshold	Criteria Check
1	Sales to private sector of (i)/Sales to public sector of (i)	1,4	1,25	>1.25	PASS
2	Exports of (i)/Total sales of (i)	0,29	0,25	>0,25	PASS
3	Specialization index of (i)	3,5	2	>2	PASS
4	Imports (intermediate goods) for (i) Total sales of (i)	0,4	0,25	>0,25	PASS
5	Number of technicians/Total number of employees	0,27	0,15	>0,15	PASS
6	Number of scientific personnel/Total number of employees	0,04	0,03	>0,03	PASS
7	R&D expenditures/Total sales	2,8	1,9	>1,9	PASS
8	Investments in equipment/Total sales	0,28	0,22	>0,22	PASS
9	Investments in dwellings/Total investments	0,21	0,18	>0,18	PASS
10	Sales/Number of employees	69	63	>63	PASS

Note
1. In this table, the following data are presented:
a) The contractor's index for all 10 indicators
b) The average value of these indicators at the EU level, concerning the same business sector with that of the contractor (e.g. telecommunications)
c) The criteria threshold that contractor should satisfy in order to be "good"
d) The results of the criteria check that, show whether the criteria are satisfied (pass) or not satisfied (fail)

Table 1: Examination of Contractor's Indicators[1].

Criteria satisfaction	Characterization of Contractor
Satisfaction of all 10 criteria	"Good"
At least one criterion failed	"Bad"

Table 2: Characterization of a Contractor.

No	Criterion (Indicator)	Weight
1	Sales to private sector of (i)/ Sales to public sector of (i)	20%
2	Exports of (i)/Total sales of (i)	15%
3	Specialization index of (i)	12%
4	Imports (intermediate goods) for (i) Total sales of (i)	7%
5	Number of technicians/Total number of employees	5%
6	Number of scientific personnel/Total number of employees	7%
7	R&D expenditures/Total sales	7%
8	Investments in equipment/Total sales	6%
9	Investments in dwellings/Total investments	6%
10	Sales/Number of employees	15%
	Total	**100%**

Table 3: Weights of the Criteria.

to establish the surveillance mechanism on national or EU level.

It is clear now that the importance of the failure to satisfy a criterion depends on the weight of the criterion itself. For instance, the failure of criterion #1: "Sales to private sector/Sales to public sector" is much more important than the failure of criterion #5: "Number of technicians/Total number of employees". The weights in Table 3 indicate the importance of every criterion but provide no indication of how close a criterion is (or it is not) from being satisfied. This is the reason the second design choice, explained below, is made.

The possibility each criterion to be partially satisfied is introduced

Instead of each criterion to be either satisfied or not satisfied (in a strict black or white way), a fuzzy grey-transition zone is introduced between these two states. This is implemented in the following way:

(1) The criterion threshold that corresponded to the average index of EU level (Table 1) now corresponds to the "high pass" for each criterion (value b in Figure 2). This means that a contractor with a higher index than the "high pass", satisfies completely the criterion and consequently the value of the membership function [41], for the specific criterion, is 1 (the contractor belongs completely to the set of "good" contractors as far as the specific criterion is concerned).

(2) A new "low pass" threshold is introduced (value a in Figure 2), which has a value lower than that of the "high pass" threshold. This "low pass" threshold has the following meaning: a contractor with an index lower than the low pass value does not at all satisfy the criterion and consequently the value of the membership function of this contractor to the fuzzy set of "good" contractors for the specific criterion, is 0 (the contractor does not at all belong to the set of "good" contractors as far as the specific criterion is concerned).

(3) If the contractor has an index lower than the "high pass" threshold value but higher than the "low pass" threshold value, then the contractor satisfies only partially the criterion. The value of the membership function of this contractor for the specific criterion #i is a decimal value Vi between 0 and 1 that corresponds to the degree that the contractor satisfies criterion #i. The closer this value is to 1 the better the contractor is. As it is shown in Figure 2, the classical linear membership function was chosen for the transition phase [43]. The evaluation of value Vi based on Figure 2 is given by equation

$$V_i = \frac{x_i - a}{b - a} \quad (2)$$

where: xi is the index of the contractor for criterion i

From the above design choices, we end up with a degree of satisfaction for each of the 10 criteria. These 10 degrees, which take values within the interval [0,1], have to be aggregated to give a single value G that corresponds to the overall degree that the contractor is "good". The aggregation of these 10 values can be done in various ways [42]. The function of the weighted average is chosen, given by the following equation, which takes into account the weight of each criterion:

$$G = \sum_{i=1}^{10} V_i W_i \quad (3)$$

where: i=1…10 is the index number of the criterion

Implementation of the Fuzzy Logic System

Based on the design choices presented in the previous section, we continued with the implementation of a fuzzy logic system. As it is shown in Figure 3, the interface consists of 10 rows and 10 columns. Each row corresponds to an indicator. The columns have the following meaning:

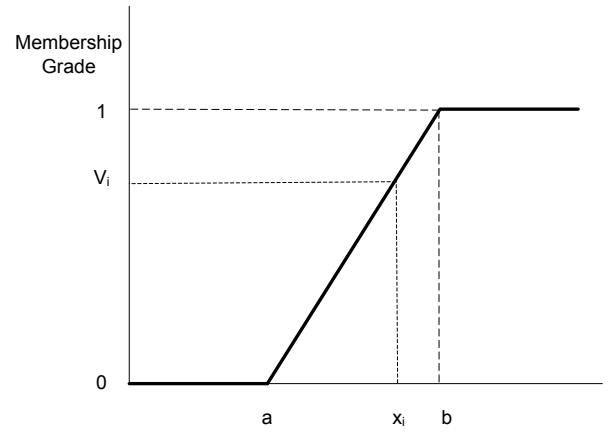


Figure 2: High and low pass criterion threshold value.

No	Indicator	Contractor's Index (xi)	Criteria Weight	Low Pass Value (a)	High Pass Value - Index of EU level (b)	Crisp Criteria Threshold	Crisp Result	Fuzzy Result - Degree of Criteria Satisfaction (Vci)	Weighted Criteria Satisfaction
1	Sales to private sector of (i) / Sales to public sector of (i)	1,2	20%	1	1,25	>1,25	FAIL	0,80	16%
2	Exports of (i) / Total sales of (i)	0,3	15%	0,1	0,25	>0,25	PASS	1,00	15%
3	Specialization index of (i)	1,8	12%	1	2	>2	FAIL	0,80	10%
4	Imports (intermediate goods) for (i) / Total sales of (i)	0,28	7%	0,1	0,25	>0,25	PASS	1,00	7%
5	Number of technicians/ Total number of employees	0,12	5%	0,08	0,15	>0,15	FAIL	0,57	3%
6	Number of scientific personnel / Total number of employees	0,028	7%	0,02	0,03	>0,03	FAIL	0,80	6%
7	R&D expenditures / Total sales	1,7	7%	1,3	1,9	>1,9	FAIL	0,67	5%
8	Investments in equipment / Total sales	0,2	6%	0,15	0,22	>0,22	FAIL	0,73	4%
9	Investments in dwellings / Total investments	0,16	6%	0,15	0,18	>0,18	FAIL	0,33	2%
10	Sales / Number of employees	70	15%	50	63	>63	PASS	1,00	15%
								Degree of Membership to "Good Contractors" is	0,820

Figure 3: Results of Fuzzy System for a quite close to "good" contractor regarding Product (i).

• Column "No": Index number of the indicator.

• Column "Indicator": Description of indicator.

• Column "Contractor's index" (User's Input): This is the only column that a user can enter data. The user enters the 10 indexes of the contractor under consideration.

• Column "Criteria Weight" (Database): The values of this column are retrieved automatically from the system's database. They correspond to the weights of Table 3. The values depend on the business sector of the contractor under consideration (e.g. telecommunications).

• Column "Low Pass Value" (Database): The values of this column are also retrieved automatically from the system's database and correspond to the low pass value provided for the each of the ten criteria. Policy makers, that are experts in public procurement, provided these low pass values after taking into consideration

a) the business sector of the contractor we examine (e.g. telecommunications)

b) the standard deviation of each of the 10 indicators at the EU level.

• Column "High Pass Value – Index at the EU level" (Database): The values of this column are retrieved automatically from the system's database and correspond to the values given by the EU statistics. Different values exist for each business sector.

• Column "Crisp Criteria Threshold" (Database): This column presents the threshold that the contractor should pass in order to be characterized as "good", using the strict black or white method.

• Column "Crisp Result" (Evaluated): The values of this column are evaluated by the system, depending on whether or not the contractor passes the corresponding threshold of the previous column. If all the values of this column are equal to "pass", then the contractor is characterised as "good". These thresholds have been adopted and used, by various empirical researches in the past, Commission of the EC [43].

• Column "Fuzzy Result–Degree of Criteria Satisfaction" (Evaluated): The values of this column are evaluated by the system using equation (1) for each of the 10 criteria. This column provides all the important information about the degree that each of the criteria is satisfied (best value=1, worst value= 0).

• Column "Weighted Criteria Satisfaction" (Evaluated): The values of this column are also automatically evaluated by multiplying the value of column "Criteria weight" and the value of column "Fuzzy Result". This gives each sub product of equation (2).

At the right bottom corner of Figure 3, the sum of the values of column "Weighted Criteria Satisfaction" is calculated. This is the overall result (value of G in equation 2). This value represents the degree that the contractor belongs to the set of "good" contractors regarding Product (i).

In the example of Figure 3, the indexes of the contractor are such that some criteria fail to succeed. According to the crisp way, this contractor would not be considered as a "good" one. On the other hand, because the indexes of the contractor are not quite below the thresholds, the result of the fuzzy logic system is that the contractor belongs to the set of "good" contractors to a degree of 0.820, which is quite close to the top value 1.000. This means that the contractor can also be considered as almost "good" contractor. This is a clear result even though many of the criteria may not be satisfied in the strict black or white way. The degree that each criterion contributes to the final result is shown in Figure 4.

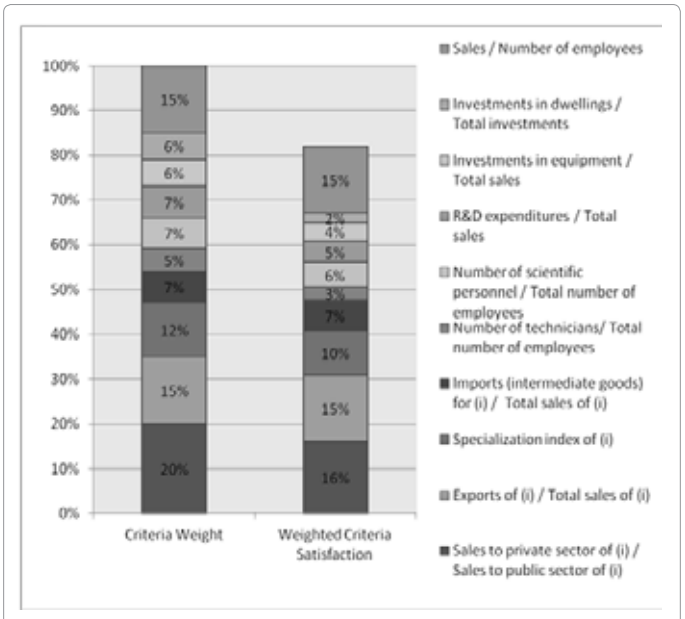


Figure 4: Analysis of the contribution of each criterion to the overall 0.820 degree of membership of the contractor of Figure 3, to the set of "good" contractors.

No	Indicator	Contractor's Index (x)	Criteria Weight	Low Pass Value (a)	High Pass Value - Index of EU level (b)	Crisp Criteria Threshold	Crisp Result	Fuzzy Result - Degree of Criteria Satisfaction (Vci)	Weighted Criteria Satisfaction
1	Sales to private sector of (i) / Sales to public sector of (i)	0,8	20%	1	1,25	>1,25	FAIL	0,00	0%
2	Exports of (i) / Total sales of (i)	0,26	15%	0,1	0,25	>0,25	PASS	1,00	15%
3	Specialization index of (i)	1,2	12%	1	2	>2	FAIL	0,20	2%
4	Imports (intermediate goods) for (i) / Total sales of (i)	0,09	7%	0,1	0,25	>0,25	FAIL	0,00	0%
5	Number of technicians/ Total number of employees	0,12	5%	0,08	0,15	>0,15	FAIL	0,57	3%
6	Number of scientific personnel / Total number of employees	0,018	7%	0,02	0,03	>0,03	FAIL	0,00	0%
7	R&D expenditures / Total sales	1,4	7%	1,3	1,9	>1,9	FAIL	0,17	1%
8	Investments in equipment / Total sales	0,2	6%	0,15	0,22	>0,22	FAIL	0,71	4%
9	Investments in dwellings / Total investments	0,35	6%	0,15	0,38	>0,38	FAIL	0,33	2%
10	Sales / Number of employees	48	15%	50	63	>63	FAIL	0,00	0%
								Degree of Membership to "Good Contractors"=	0,277

Figure 5: Results of Fuzzy System for a quite close to "quite far from good" contractor regarding Product (i).

A second example can be examined, providing different results for another contractor. Analytically, the indexes of this contractor are entered into the system and the results are shown in Figure 5. For this contractor, once again, most of the crisp criteria were not satisfied. Similar to the case of Figure 3, the contractor would not be characterized as a "good" contractor. The important information of the fuzzy logic system is that this contractor belongs to the set of "good contractors" only to a degree of 0.277, which is quite below the top value 1 and significantly lower that the degree of the contractor of the case in Figure 3 (0.820). The degree that each criterion contributes to the final result is analysed in Figure 6. The above means that although in the crisp way, contractors of Figures 3 and 5 are determined as just not "good" contractors, with the use of the fuzzy logic system, the first one is characterized as quite close to the set of "good" contractors and the other one quite far from being a "good" contractor. In the latter case, the surveillance authorities may need to interfere.

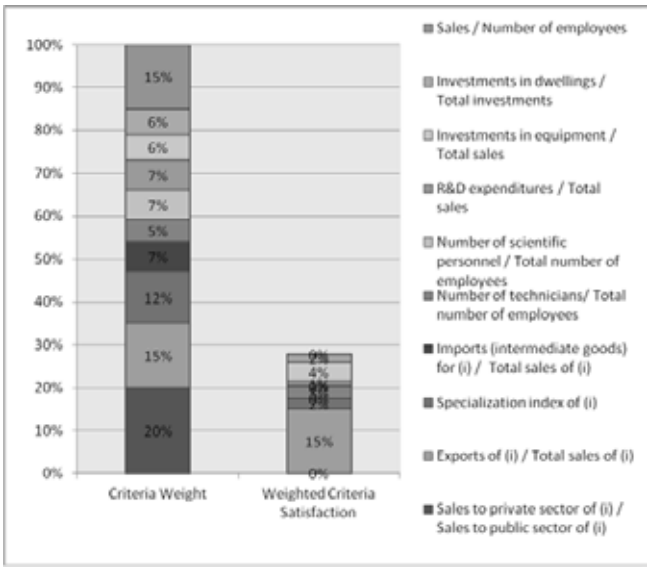


Figure 6: Analysis of the contribution of each criterion to the overall 0.277 degree of membership of the contractor of figure 5, to the set of "good" contractors.

Conclusion Remarks

In this study, a monitoring process for public procurement is proposed, that applies mainly to goods and services and is integrated to the current public procurement process and. The proposed system aims at assisting this monitoring process, by providing indications regarding the degree to which a contractor seems to be "good" for the supply of Product (i) that the contract refers to, or for example, to what level "buy national" practices are applied. This can be done by examining specific indicators that refer to the contractor.

The monitoring process uses a fuzzy logic system that based on a) specific criteria, b) EU statistics and c) contractor's data, identifies the degree to which a contractor belongs to the fuzzy set of "good" or "bad" contractors, regarding the supply of Product (i). In cases where the fuzzy logic system gives results of low membership grade of a contractor to the set of "good" contractors, there is a strong indication either of "buy national" policies or corruption or both of them. This is rather useful for monitoring authorities because the huge number of contracts makes impossible the thorough examination of all suppliers' efficiency. Using the system above, all cases can be hierarchical sorted, with the most problematic to be identified and examined first.

The system described above is applied at the stage right after the awarding process. Moreover, in the future, the method can be part of the selection process, e.g. can be applied before the awarding process. In this case, the system can help in identifying how efficient candidate suppliers are, through an alternative way (e.g. relative values) and not through the existing selection process which is based on absolute values. In this way, the fuzzy logic system will operate as a decision support system rather than as a monitoring system. However, such a proposal implies the revision of the EU directives referring to the economic and technical capacity of the supplier. It consequently inserts the need of the redesign of the selection stage of public procurement. It introduces an alternative selection process, fully compatible to e-procurement systems launching besides anticorruption mechanisms.

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