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Final Supplier Selection System in Military Critical Items

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Abstract

The financial plans of the Greek Ministry of Defense (MoD) for the year 2013 include a big amount of money in support of the national defense system. Nevertheless, comparing MoD's annual budgets of the last two years, we can see that in 2013 less money than in 2012 were allocated to the MoD by the Government. This budgetary reduction could lead to the need for improvement in all phases of MoD's function so that with limited resources, an even better result can be achieved. Supplier selection procedures could not be an exception, especially when it comes to critical supplies and services. Selecting Suppliers in military Critical Safety Items has multi-level features and many factors get involved. This paper develops a conceptual evaluation model based on Public Procurement Law in Defence (3978/2011), Analytic Hierarchy Process and Fuzzy Technique Order Performance by Similarity Ideal Solution. Multivariate Statistical Analysis (i.e. Principal Component Analysis, Factor Analysis and Cluster Analysis) and Quality tools are added to the model, while Business Intelligence/Competitive Intelligence is proposed as an additional tool to deal with the strong competitive environment of our days in a worldwide level. The use of Voronoi diagrams is also suggested as a technique that could affect criteria which are linked with the location of a potential supplier. We believe that the proposed model could end up in improving supplier selection procedures as it integrates contemporary approaches seen in the relevant academic literature with some of the particularities of the Armed Forces.

JEL Classifications: H56, H57, L39.
Keywords: Military Critical Items, AHP, TOPSIS-Fuzzy TOPSIS, Multivariate Statistical Analysis, Business Intelligence, Voronoi Diagrams.

1. Introduction

Handling supplier agenda is a part of military leadership as stated by Wong *et al*. (2003). More specifically, he argues that the extended multilevel leadership

model begins with an examination of the external environment facing military leaders at the highest levels of leadership which he divides into two partially overlapping parts: the general and specific environments. The general environment, which includes the socioeconomic, educational, legal–political, and cultural aspects, usually operates within a specific geographic area. The specific environment is comprised of the suppliers, distributors, government agencies, and competitors with which a military organization should interact.

European Directive 2009/81/EC, transposed into Greek Law via Law 3978/2011, has established a new frame for public defence procurement. In this study, following its basic structures and remaining under its protective shell, i.e. what it is suggested herein does not come in contrast with any of the articles of the Law 3978/2011, we will try to present a procedure for the implementation of statistical and mathematical techniques in selecting a supplier of military critical items, in the Hellenic Armed Forces. This implementation could provide a framework that would reduce the variability stemming from the subjectivity of human decisions. Moreover, we provide an idea of what a critical item is considered to be in the defence industry, where both bottleneck and critical items could be seen as military critical items. This article aims to combine the special characteristics of the procurement processes, usually urgent, inside the field of the armed forces with new procedures already being applied in supplier selection area adjusted to the spirit of the military procurement. What can be said for that spirit, if we consider Safety Regulations, is that it is characterized by the need for quick, cost-beneficial and effective decisions that will reassure maximum availability of weapons used within the armed forces, the existence of various classified documents that regulate internal procedures, and the need for a team leader in every step of them (procedures), who is obliged to report to the Hierarchy.

More specifically, it constitutes an attempt to create a procurement decision model by taking into account supplier selection methods/models seen in several, relatively new, studies (Cheng *et al*., 1999; Petroni and Braglia, 2000; Liu and Hai, 2005; Bottani and Rizzi, 2008; Guler, 2008; Dağdeviren *et al*., 2009), the armed forces particularities and the use of statistical methods.

We think that the suggestion of a model of that kind contributes to a professional field where, to the best of our knowledge, there is still work to be done with sophisticated statistical methods, contemporary supplier selection and quality, approaches and tools. Dağdeviren (2009) also stated that limited publications exist in the area of weapon selection. Finally, we believe that it will assist the personnel involved in the aforementioned procedures to reduce costs, achieve better quality for the items under procurement and improve delivery times.

The rest of the paper is organized as follows: In the next section we review parts of relevant literature and present our conceptual framework. Then, the

phases that comprise the selection model/procedure are described, and conclusions, limitations and directions for future research are cited.

2. Literature review

Generally speaking, four major research areas exist in the supplier selection literature: (1) problem definition, (2) formulation of criteria, (3) prequalification of potential suppliers and (4) final selection of the ultimate supplier (Sen *et al*., 2008).

In this article we focus on areas (3) and mainly (4), mostly due to the limited literature that exists for areas (1) and (2) (Dulmin and Mininno, 2003) and the sensitive nature of Critical Safety Items (CSI) in the armed forces. CSIs are parts/items with special technical characteristics, requiring special treatment and maintenance procedures, whose failure could cause loss of life, permanent disability or major injury, loss of a system, or significant equipment damage (Defense Acquisition Guidebook, 2010 and ACSIMH, 2005). Using this definition in area (1), we try to ensure that available and capable suppliers exist for parts that are essential for a main system's capability to fulfill its defensive role. Normally, many of these items are marked with special codes in various technical manuals and e-data bases such as FED LOG (Supply Chain Material Management Regulation, 2003). Nevertheless, selecting these parts is not just a simple procedure, as the opinion of the responsible technician always counts in the final characterization of a part as a CSI, due to his/her everyday field experience.

We could state that if we use the purchasing portfolio analysis (Laios, 2010) as a selection method for the CSIs and the aforementioned information, CSIs could be the High Risk and High Volume Items (Strategic), whereas other items, such as items in Safety of Flight technical bulletins (Army Aviation Accident Prevention Program, 2010) could be the High Risk and Low Volume ones (Bottleneck). Another method widely used for the selection of critical parts is "Pareto Analysis", where high value added parts are characterized as critical (Krause *et al*., 1998 and Lee *et al*., 2001).

Lee *et al*. (2001) argued that the methods commonly used for supplier selection could be divided in two categories: mathematical programming models (goal programming, multi-objective programming, etc.) and weighting models (linear scoring, analytic hierarchy process-AHP, analytic network process-ANP, etc.). Weber (1991), in his fundamental research, distinguishes 3 general categories: linear weighting models, mathematical programming models, and statistical/probabilistic approaches (i.e. stochastic economic order quantity model). Nevertheless, since the 1990's, new techniques have appeared such as total cost of ownership, human judgment methods, statistical analysis, discrete choice analysis experi-

ment, and neural networks (Paton, 1996; Siying, 1997; Verma and Pullman, 1998; Degraeve, 2000).

Regarding statistical/probabilistic approaches, we observed that techniques from Multivariate Statistical Analysis (MSA) are used in supplier selection procedures. More specifically, Petroni and Braglia (2000) use Principal Component Analysis (PCA) and argue that Confirmatory Factor Analysis (CFA) can be seen as an alternative method of PCA which is used for the evaluation of supplying critical items. Hsu *et al*. (2006) distinguish supplier selection procedure into 3 large categories (supplier quality, supplier service, and strategic/management fit) and use statistical techniques (i.e. PCA, CFA) to test their hypotheses. Bottani and Rizzi (2008) used an integrated approach of Cluster Analysis (CA) and Multi-Criteria Decision-Making (MCDM) techniques for the selection of the most suitable dyad supplier/purchased items.

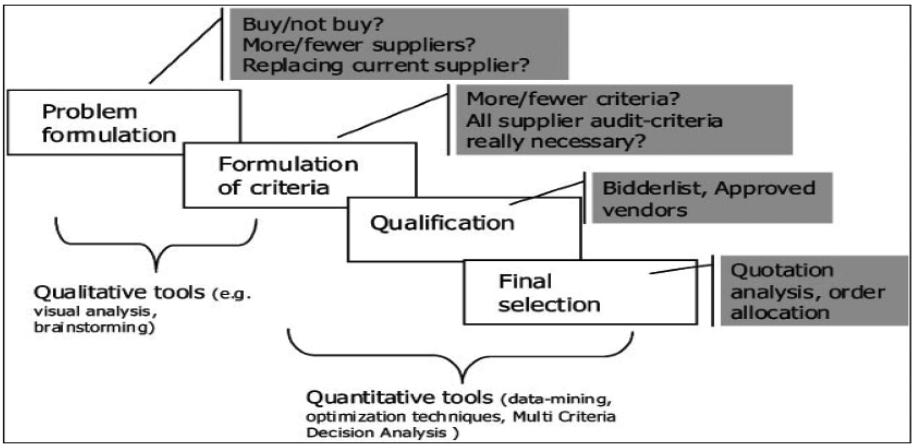
As far as armed forces are concerned, experience has always played an important role in the Design and Execution of various missions (Lt General Pagonis, 1992). This enables us to say that some criteria for selecting suppliers could be based in Case-Based Reasoning (CBR) method, a decision support tool found in the academic literature (Ng and Skitmore, 1995). In this article, the proposed CBR system may be based on information provided by an existing military data base containing older similar cases of CSIs procurement. To the same direction, De Boer *et al*. (2001) argue that data mining techniques may also be used to analyze similar decisions made in the past, in order to derive general patterns and decision rules that may subsequently be used to improve the efficiency and effectiveness of future decisions. De Boer *et al*. (2001) demonstrate in the following Figure 1 possible methods for the major areas in supplier selection.

They also point out that, in case of bottleneck and strategic items, narrow limits for supplier selection exist due to the high supply risk (i.e. unique item specification, scarcity of the material, etc). Laios (2010) proposes strategically long lasting coalitions with suppliers when strategic items are involved. Therefore, we understand that the procedure for a selection of a CSI supplier should be structured under a solid base. The complexity level of this structure would be higher, if we take into account that:

a. Dulmin and Mininno (2003) indicate a generalized tendency to enlarge the set of evaluative attributes beyond the traditional ones such as quality, delivery speed, reliability and price, leading to the increase of sophisticated supplier selection models. They also note the need for more sophisticated criteria as the relationship with the supplier becomes closer and longer.
b. Hsu *et al*. (2006) report that, while management becomes more reliant on strategic suppliers, selecting the right ones becomes harder due to the fact that there is no consensus regarding the most important selection criteria.

FIGURE 1

Rough positioning of decision methods in supplier selection



Source: De Boer *et al*., 2001.

A characteristic example that shows the seriousness and complexity of selecting a key supplier is described in one of the studies on defense industry supply chains (Hartley, 2007). More specifically, it was found that, in UK armored fighting vehicles, the prime contractor had nearly 200 first tier suppliers, each of them had an average of 18 second tier suppliers and, finally, each of the second tier suppliers had an average of 7 third tier suppliers.

According to Chopra and Meindl (2004), in the majority of case studies supplier scoring and assessment refers to the following factors, besides quoted price: replenishment lead time, on time performance, supplier flexibility, delivery frequency/minimum lot size, supply quality, inbound transportation cost, pricing terms, information coordination capability, design collaboration capability, exchange rates, taxes and duties, and supplier viability. Of course, it is not required to take into account in a supplier selection process all the factors mentioned above.

An interesting approach in chapter 2 of the Defense Acquisition Guidebook (2010) points out as a critical factor for a contact award, a supplier's capability to deal with unexpected rise of a standard order quantity at a percentage commonly agreed with the customer. It could be related with the article of Soukup (1987) and it could also be simulated with supplier flexibility (Chopra and Meindl, 2004). Article 36 of Hellenic Law 3978/11 also mentions the same factor as a part of "Supply Safety".

Department of Defense (DOD) Aviation Critical Safety Item Management Handbook-ACSIMH (2005) guides towards the evaluation of supplier's historical

functional reports, puts a lot of weight in quality matters and points out that key suppliers should be able to perform special tests in order to deliver reliable final products. Government Quality Assurance Regulation (GQAR, 1998) contains some parameters/prerequisites that could be seen as supplier requirements, such as the existence of a quality plan for the products, the capability of providing a Certificate of Conformity (COC) duly signed and the provision of an ISO 9001 or NATO AQAP 2000 Series Certification, whenever such a parameter is requested.

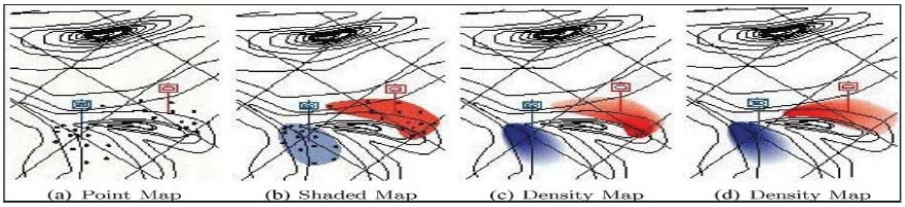
Hartley (2007) argues that the arms market is an imperfect market due to its domination of oligopolies on the supply side. As far as selection criteria are concerned, it raises a point on what the procurement agency has to decide for. The choices will be based either on military criteria (e.g. cost, quality, delivery dates) or on economic and industrial criteria (e.g. jobs, technology, exports). Finally, as the author says, it considers the whole subject as a related issue of who chooses: *"the procurement agency or the government with its concerns about local jobs and re-election"*?

In mathematics, a Voronoi diagram is a special kind of decomposition of a given space, e.g., a metric space, determined by distances to a specified family of objects (subsets) in the space. It is the technique that enables the division of such multi-dimensional spaces into subspaces. Voronoi diagrams can be found in a number of fields in science and technology and they have several applications (Novaes, 2009; Stathopoulos, 2010).

Kim and Hoffmann (2003) use these diagrams in the area of military command and control matters and claim that as a tool it will provide a military commander, among other things, with good situation awareness in a sharp and user-friendly way. Their contribution to a correct depiction of troop's density appears clearly in the following figure which exists in the same article. In map (a), where an individual battle unit is displayed as a point, it takes some time to recognize the whole troop boundary and concentration. In a shaded map (b), the troop boundary becomes easy to recognize, but it is still hard to see the troop concentration. In density maps (c) and (d), the troop concentration becomes apparent, verifying the fact that a correct understanding of the troop concentration depends on a correct display.

FIGURE 2

Voronoi Diagrams as shown in the article of Kim and Hoffmann (2003)



Stathopoulos (2010) uses Voronoi diagrams to calculate the optimal place for the installation of Postal Office (PO) stations and bank ancillaries along their ATM's. He also points out that these diagrams could be useful in optimizing the location of critical public services, such as police departments, fire stations and ambulances.

Applications of Business Intelligence (BI) which is a newer term for decision support systems, executive information systems, and management information systems (Thomsen, 2003), could be implemented in the last three areas of supplier selection. In general, BI is used to understand the capabilities available in the firm (Negash, 2004): the state of the art, trends and future directions in the market, technology, regulatory environment in which the firm acts, actions of competitors and implications of these actions. As a research field, BI encompasses data and knowledge management, modelling of processes and policies, data quality, data privacy and security, data integration, data exchange, information retrieval, data mining, analytics, and decision support (Jiang *et al*., 2011).

BI has an important role in formulating strategy (Herring, 1992). More specifically, Herring (1992) argues that BI plays many (six) roles in understanding current and future competitive environment and revealing weaknesses of the potential supplier. It helps in realizing how the other players in the competitive environment are responding, including the customer, suppliers and the government when regulatory issues are involved. Extreme interest presents Competitive Intelligence (CI), a special branch of BI also seen in economic espionage (Konstantopoulos, 2010). Competitive Intelligence is a systematic and ethical program for gathering, analyzing and managing external information that can affect plans, decisions and operations (Negash, 2004). A big percentage of the "incoming intel", comes from open sources (government websites and reports), private sector sources (competitors, suppliers, distributors), media (journals, wire services, newspapers, financial reports) etc. (Imhoff, 2003).

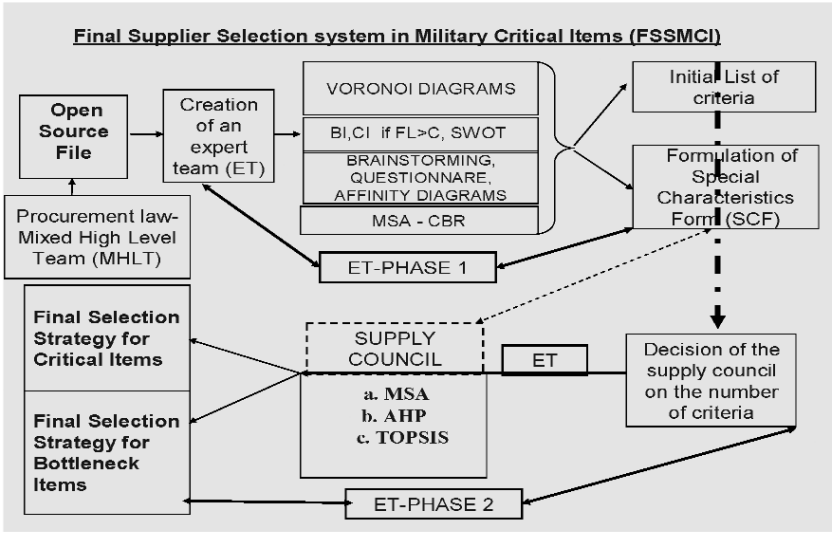
3. Conceptual framework

In this article, we propose an outline of a supplier selection decision-making process, focusing on its final two steps. It is supposed that we work in a defense organization operating under public procurement law and the items under consideration for purchasing, have been already defined by the Operational Branch.

Moreover, as it was mentioned above, the decision-making process in selecting Military Critical Items should not be time consuming. Therefore, we implement the idea of merging phase 2 (formulation of criteria) with phase 3 (qualification) in order to perform them at the same time. Figure 3 depicts schematically our intention about what we call in this article "Final Supplier Selection system in Military Critical Items (FSSMCI)".

FIGURE 3

The Final Supplier Selection system in Military Critical Items (FSSMCI)



The remaining of this article is devoted to the explanation of the most important issues presented in Figure 3.

3.1 Phase 1: Decision Method for the Pre-Qualification of Potential Suppliers

It is clearly necessary to create a Source File which will comply with the public law procurement rules. This file will contain all possible suppliers who have the basic prerequisites determined by the National and European legislation in defence and security area. The award of works, supplies and service contracts in this area is governed by Directive 2009/81/EC, which has been transposed into Greek Law via Law 3978/2011 that replaced Law 3433/2006.

Chapter E of Law 3978/2011, under the title ”Quality Selection-Pre selection”, contains articles such as 57, 58 and 59 which refer to legal constraints regarding the personal situation of the candidate or tenderer, his/her suitability to pursue the professional activity and his/her economic and financial position. Laios (2010) states that the vast majority of routine supply activities are governed by the National and European Law. Therefore, a team of managers (Mixed Mid Level Team or MMLT), law experts and buyers could be created in order to determine the basic parameters that will allow a potential supplier to register to the Source File. This team could also employ certain chapters of the GQAR where, as already mentioned, some prerequisites exist for assessing a supplier’s suitability for the Source File.

Based on article 108 of Law 3978/2011 and due to the fact that Greece is a member of various international organizations with geopolitical interests, it would be wise to enrich that team with members of the General Directorate of National Defense Policy and International Affairs (GDNDPIA). This would ensure that suppliers who enter the Source File come from countries which share the same values and goals. A characteristic reference for a Source File of that kind can be found in a document issued by the NATO Maintenance and Support Agency (NAMSA), now called NATO Support Agency (NSPA). Functional Directive 251-01 (2012) describes the procurement rules of that Agency, where it is clearly stated that suppliers' eligibility should be based on the following criteria: residency, national eligibility status, present capability, and past performance.

The next step is the creation of the Expert team (ET). This body will do all the work in order to bring final results of the selection process to the Supply Council (SC). Dağdeviren *et al*. (2009) stated that an expert team was created by three junior managers of the Turkish defence industry firms and the authors in order to determine, based on their past experience and background, all supplier selection criteria presented in that article. Based on Dağdeviren *et al*. (2009), we suggest that the ET could be composed, mainly, by junior managers of the defence organization and members of the supply department (i.e. material controllers). Additionally, it could have as members:

a. A representative of the legal department specialized in Commercial Law, which will participate in both phases of the ET as they are depicted in Figure 3. This idea is intensified by the fact that Yuva (2001) stresses out the need for strong and continuous co-operation with the legal advisors of an organization, in order to achieve the establishment of efficient and effective contracts between the parties involved.
b. A group of two to three military members straight from the Unit, which used or intends to use the item under purchasing consideration. This is suggested in accordance with Total Quality Management perception and, specifically, with the structure of the Quality Cycle Team (QCT) and the Commission for Improving Quality (CIQ), as mentioned in Total Quality book (2000) issued by the Hellenic Open University (HOU). In this way, we can implement the idea of integrating decision-making teams with lower level employees. These employees, due to their experience, can significantly contribute towards a realistic choice.

The senior member of the Expert Team, which will report directly to the chairman of the Supply Council, is another crucial issue. What we think is that he/she should be the Quality manager. Modern perception of the supply management points out the need for intraorganizational cooperation (Laios, 2010).

This can be ensured by a quality manager with the capabilities analyzed in chapter 5 of the Total Quality book of the HOU (2000).

In Figure 3, among others, we presented the primary sources of the initial criteria list, besides experience and personal background, which may lead to the formulation of a list called "the special characteristics form", also described in the Quality Planning book of the HOU (2000). A form, which may contain results about desired special features of the suppliers under consideration, that the ET or the SC (at its initiative), may add or pinpoint based on their aspirations from the potential supplier and their experience, on a case by case procurement scenario.

For example, in the case of an evaluation of a potential air parts supplier, it is likely that the ET or the SC may want to investigate his capability of providing adequate certificates recently issued, to prove part's suitability for safe use and its high quality standards. This kind of requirement may not be necessary when evaluating a supplier of vehicle parts where no such high quality demands exist or danger for the personnel involved.

Voronoi Diagrams are adaptable geometrical structures that could provide the optimal locations for a number of points of interest (Stathopoulos, 2010). Laios (2010) indicates the cost of transportation as a factor of great financial interest, which can affect a supply decision. Chopra and Meindl (2004) support the idea that the measurement of supplier performance should be based on eleven criteria, which include dimensions affected by the location of the potential supplier, such as inbound transportation cost and delivery frequency. Consequently, if we considered a place in a given space as the centre-point of our procurement activities, it would be interesting to use Voronoi diagrams in order to find the optimal location for a potential supplier.

The 25 most usable tools and techniques for improving quality, as reported by the ISO, are shown in HOU's Total Quality Book (2000; Table 6.6, p. 78). We will use two tools that can assist the selection of the appropriate Multi Criteria Decision Method (MCDM) to solve the supplier selection problem. The rightness of the procedure is connected to the need for analysts (ET) and decisions makers (SC) to understand the problem, the feasible alternatives, the different outcomes, the conflicts between criteria and the level of the data uncertainty.

The table mentioned above shows that brainstorming is focused on defining the problem while Affinity Diagrams are used in both stages of defining and analysing the problem. Both of these tools could assist ET members to avoid noisy data (i.e. data that contain rounded figures or estimates and create uncertainty in decision-making process) in order to present various ideas for criteria in a manner that can be friendly for the decision makers (SC). A questionnaire should also be used by the ET to assist in the formulation of the way potential suppliers perceive matters that are important for an organization (e.g. quality and safety standards,

ability to respond in unexpected alteration of the quantity ordered, willingness to provide a cost reduction in administrative expenditures over a certain time period in case of a contract award and supplier's discount policies). Needless to say that the questionnaire may contain issues that the SC would like to add and that the ET may also take into account information gathered from other tools (e.g. brainstorming, BI/CI). After its design, it should be submitted for evaluation and approval to the SC, prior to its dispatch to the potential suppliers.

James H. Thomas, a market intelligence consultant who served for 26 years as an intelligence officer, stated in 2001 that the primary goals of Business Intelligence are:

- Avoid surprises and identify threats and opportunities.
- Understand where a company is vulnerable and decrease reaction time.
- Out-think the competition and protect intellectual capital.

In our case, BI/CI tools can be used as a source for the formulation of SWOT (Strengths, Opportunities, Weaknesses and Threats) analysis in order to assist the evaluation of a potential supplier. These tools incorporate the intelligence required to compare strong and weak points of potential suppliers and see if our organization's weak points are neutralized due to the strong points of the finally selected supplier. Laios (2010) uses Figure 4 to show the application of SWOT analysis for the evaluation of a potential supplier. In this case, all of its segments could be BI/CI "targets"- objectives for our organization.

FIGURE 4

SWOT Parameters: Objectives for BI/CI

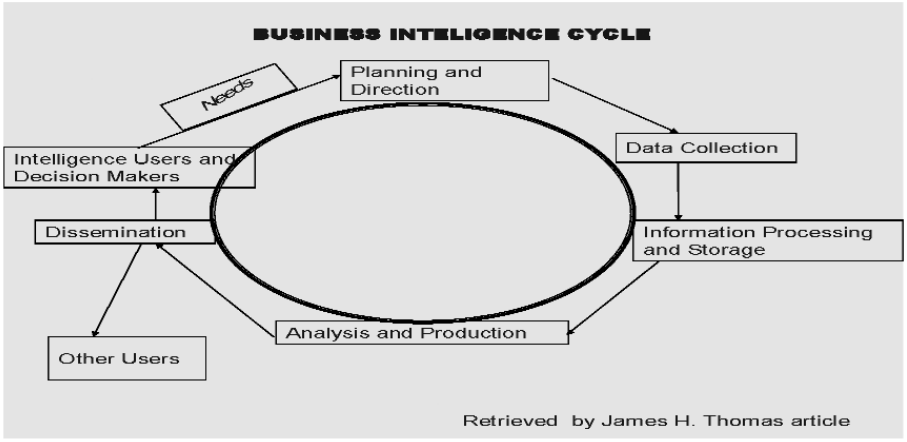
POTENTIAL SUPPLIIER	
Strengths	**Weaknesses**
Special Technology	Limited product variety
Consistency in his/her contractual obligations	Non decisive management
High quality of product or service	Small size of business
Opportunities	**Threats**
Advantages in case of differentiation with other potential suppliers	Co-operation of the potential supplier with another defence organization with opposite interests
Potential co-operation with our defence organization in planning, quality and cost reduction	Loss of expertise by a competitor or non alignment with current technology
	High cost of the supplier

BI/CI can even help in adjusting SWOT in terms of strategic business models, if somebody wants to build business schemas (Jiang *et al*., 2011). BI/CI is proposed by Okkonen *et al*. (2002) as a tool for improving the performance of an organization if used simultaneously with other management tools, such as performance measurement and knowledge management.

Figure 5 demonstrates the Business Intelligence Cycle (Thomas, 2001), which is referred to the stages for analyzing the Intel received by BI/CI tools. Decision makers in our case are considered to be the Supply Council. An example of what a BI target could be is the knowledge of the figures that compose the Procter & Gamble prefect order concept, as cited in Laios (2010) when such historical data do not exist, or other data showing a supplier's financial/operational status, trends and positioning.

FIGURE 5

Business Intelligence Cycle



Of course, BI/CI is not cheap, due to the variety of costs (e.g., hardware, software, implementation and training) incorporated in this system (Negash, 2004). After reviewing carefully NSPA regulation (NSPA FD 251-01, 2012), we propose the implementation of BI/CI methods only in contracts of an estimated value of Financial Level C or above (e.g., pp. 11 and 21 of the aforementioned NSPA regulation). This is the level which indicates the high budget of a contract award performed under the aforementioned NSPA regulation, where more complicated procedures apply. The reason why this is proposed stems from the fact that this regulation urges for special treatment to the contracts with a FL of at least C.

Indicatively, we can mention that in case of such contracts, NSPA has established procurement procedures in the scope of ensuring the participation of as many candidate suppliers/bidders as possible and providing a more reliable and objective selection procedure. For example in p. 14 of the abovementioned Directive (FD 251-01) it is stated that "For procurements with an estimated value of FL C or above, all known qualified sources will be solicited", while the Market Research & Competition Advocacy Section for publication on the NAMSA website is also activated in similar cases (FL above C).

Nevertheless, BI/CI effectiveness is proved in various cases, such as the case of company named "Illuminet", which managed to stay a step ahead from its competitors, when it used a vendor (QL2 Software) to retrieve information posted on their web sites (Moores, 2003).

In accordance with Sen *et al*. (2008), the Information Technology (IT) department of the Company/Organization should have the ability to create software driven database, where information in the form of previous decision making cases is stored, in order to see which of the old cases matches best with the new one using the parameters of the new case.

By this use of a CBR system, the ET in cooperation with the IT department would easily retrieve some criteria that were important in older similar cases. We believe that one output of the CBR-system could be again the Procter & Gamble perfect order concept (Laios, 2010), if no sufficient intel. is gathered by BI applications. A well known multinational company, such as P&G, estimates the cost of an "imperfect order" at 200 US$, while it claims that "perfect order concept" plays a big role in clients' perception about the company.

MSA methods are suggested to assist ET when:

a. The number of the gathered initial criteria is great. In this case, we could use PCA, a statistical analysis used to reduce the criteria by identifying a small group of variables that are responsible for a large part of the total variance in the original variables (Johnson and Wichern, 2007).
b. The number of the suppliers involved is great. Sen *et al*. (2008) argue that Cluster Analysis (CA) can deal with a large set of suppliers and it is useful in the prequalification phase which could be simulated with the set of activities of ET's Phase 1. Using CA, smaller groups can be created, which will contain suppliers that fall short in a number of important (to the ET) criteria or have extra capabilities worth to be mentioned to the SC.

Reaching the end of a rough description of Phase 1, we have suggested a way to formulate an initial list of supplier selection criteria and studied European and National legislation as well as other tools. We have also described the purpose of the special characteristics form included in Phase 1, which the ET would like to pinpoint to the SC or the ET has been ordered by the SC to evaluate, as

well as the feedback of the questionnaire. For example, National Safety Regulation, which is a classified document, forbids certain things and, thus, the ET should be aware of it. Top Management should ensure that all members of ET and SC are authorized to use National Safety Regulation.

3.2 Phase 2: Decision Method for the Final Selection Phase

Prior to the final supplier selection, the SC should determine the budget that will be available to the supplier. According to law 3871/10 (article 21), every public authority should ensure, before any other action, the existence of the funds that will cover the initially estimated budget of a supply. This obligation plays a role in the structure of the SC which, if we consider the Hellenic Army General Staff-HAGS Institution as an "Organization of Public Procurement Law Supplies" and as it is presented in its official website (http://www.army.gr/default.php?pname= Epitelika&la =1), could be the following (but not limited to):

a. HAGS, Second Deputy Chief, as the Chairman or the Manager responsible of authorizing a public military procurement, in accordance with the public document F.800/133/134893/S.3323 issued in 2007 (FEK 2300B/2007) and a legal advisor that should be appointed to assist the Second Deputy Chief in relevant tasks.
b. The Head Officer of The Expert Team who will be aware of all steps made in Phase 1.
c. The Head officers of the Logistics, Technical and Finance Directorates, who ensure proper support, finance and maintenance, not only at the time of procurement, but also throughout the life cycle in the army of the items under procurement, by co-operating with the selected supplier.
d. The Head Officer of the Directorate, who will use the item under Supply, accompanied by the Commander of a Unit who will finally receive it.
e. Two Senior Officers, one from the IT department and another from the Logistics or Finance Directorate, who have attended courses in Supply Management and Statistics in National Universities.

The Supply Council will receive by the ET the initial list of supplier selection criteria, the special characteristics form, and the initial estimation of their weight. Of course, it can modify the lists or leave them fixed. In case of modification, it should take seriously into account Law 3978/11 (article 66), where indicative criteria are mentioned. Moreover, it would be helpful to have a look in the factors mentioned by Chopra and Meindl (2004), as well as in certain military criteria worth to be included at their judgement by experience (i.e. criteria mentioned in p. 6). SC is mostly responsible for assigning weights on the criteria, deciding for the rating method of potential suppliers and selecting the strategy that will be

followed in the case of critical or bottleneck items. The experience of the SC members plays a key role, as the importance of each criterion depends on its contribution to the procurement target, which, in our case, is the accomplishment of the mission by the Unit who will receive the item.

The application of AHP in Phase 2 could be very useful. This method was firstly developed by Saaty (1980) and has been used several times in the MCDM problem of supplier selection (Cebi and Bayraktar, 2003; Ho *et al*., 2010). SC can apply this method to determine the relative importance of the criteria and to augment the efficiency of weights assignment. In some cases, SC may finally use a number of criteria, which are not a part of AHP procedure, because some criteria can be of equal importance (Dağdeviren *et al*., 2009). We are reluctant to use the fuzzy AHP decision model, because the number of criteria may be great, resulting on a large number of pairwise comparisons (Shyur, 2006). However there are cases where fuzzy AHP was used in weapon selection (Mon *et al*., 1994).

MSA will assist in the additional scaling of criteria involved, especially in critical items. This is necessary due to the fact that, in case of critical items, suppliers may be few (Laios, 2010) and oligopolistic situations may appear. Moreover, as we have already pointed out, the need for long lasting, trustful and solid co-operations with the suppliers becomes evident. For example, Petroni and Braglia (2000) stated that MSA/PCA is a procedure that identifies outlying suppliers, regardless of the importance attributed by the purchasing manager to each performance parameter of the vendor. This fact leads us to the conclusion that MSA contains less subjectivity than AHP. We propose the use of MSA to the questionnaire feedback to see if the results of this method match the AHP results.

Additionally, we think that a slightly different version of Risk Priority Number (RPN) found in Quality Planning book (2000), could also be an indicator for the SC. RPN is defined as the product of multiplication of Severity, Occurrence and Detection. If we create two RPNs for each criterion determined by the SC, each would contain:

a. Severity: AHP weight. Occurrence: CBR result about its role in the past. Detection: BI/CI results about its use by other agencies or results from its use in the Internet or academic literature. Occurrence and Detection measured in 5 point Likert scale.
b. Severity: MSA result. Occurrence and Detection as in (a).

The quotient of these two numbers indicates the degree of subjectivity expressed by the decision makers in AHP as well as the capabilities/opinion that the potential suppliers express through the questionnaire.

In both categories of interest, critical and bottleneck items, Laios (2010) suggests that one of the main supply strategies should be the development of an al-

ternative suppliers system. Based on that and on the article of Dağdeviren *et al*. (2009), we have selected fuzzy Technique for Order Performance by Similarity to the Idea Solution (TOPSIS) using triangular fuzzy numbers as the method for the determination of the alternative suppliers.

4. Conclusions

The proposed model in this paper combines certain scientific and "non scientific" tools used to improve decision quality. More specifically, Voronoi Diagrams, a computational geometry technique, has some effect in a category of selection criteria (mostly in financial ones) and Multivariate Statistical Analysis is proposed for the analysis of retrieved information from various sources (i.e. past similar supplier selection cases, questionnaire feedback) and the acquisition of accurate results. Business Intelligence methods are also suggested, due to the competitive environment and the need to save as much money as possible with the possession of useful intel., which will allow the selection of the supplier who could cover the weaknesses of an organization. Consequently, by pushing a potential supplier as hard as it can be in the contract negotiation process, we could achieve the best economical result for our organization.

Analytic Hierarchy Process comes as a tool for the translation of the expert's opinion to numbers, pointing out the importance of each criterion. The weights obtained from AHP are used in fuzzy TOPSIS to determine the priorities of the alternative suppliers. We preferred the fuzzy TOPSIS and consequently, triangular fuzzy numbers to express linguistic values of the members involved in the selection procedure, whereas fuzzy AHP is avoided due to the number of pairwise comparisons that may occur if the potential suppliers are many.

Bilsel *et al*. (2006) state that multiple decision makers are better than a single decision maker, because bias and partiality in the decision process are minimized. Additionally, Dağdeviren *et al*. (2009) report that efficiency and accuracy of the decision can be enhanced by different participants from different areas. Thus, we have suggested the creation of two different teams, the Expert Team and the Supply Council from different areas of the public organization, with the Quality Manager as a common link between them, as we are also great supporters of co-operability.

5. Limitations and future research directions

In this endeavour we have to say that National Safety Regulation has always been of great importance to us, in order not to fall into classified areas. Furthermore, it is obvious that this article is based on a theoretical frame, which means that it is limited to a theoretical approach of the military supplier selection issue.

Consequently, a proposal for future research would be the replication of this study by collecting survey data to verify the model. Finally, although we have created a model for selecting suppliers of military critical items, we believe that it can be expanded, with slight modifications, in other non military areas of public procurement. These modifications will allow us to adjust the criteria to the specific characteristics of the items under procurement (e.g. defining critical items to public health cases). Of course, it can be also enriched with more mathematical models, towards the direction of effectiveness and meritocracy.

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