

RESUMEN EN CASTELLANO.

Este proyecto consiste en una revisión de diferentes métodos y técnicas empleadas como herramientas de apoyo en el proceso de selección/evaluación de proveedores. Esta revisión está basada en una investigación sobre la literatura existente en relación al tema. Basándose en una serie de artículos seleccionados los diferentes métodos son explicados y sus principales ventajas e inconvenientes son destacados. Dentro del análisis de los métodos un grupo de factores y situaciones presentes en el proceso de compra que pueden afectar a la adecuación de cada método son definidos y la idoneidad de los métodos bajo las características determinadas de cada situación son analizados y categorizados.

El proyecto se desarrolla en tres partes principales; la primera está dedicada a una explicación de conceptos generales y factores referentes a la función de compras, la segunda parte se dedica a la presentación y explicación de los diferentes métodos. Se lleva a cabo un análisis de los métodos donde se compararan y clasificarán teniendo en cuenta un conjunto de características comunes. En la tercera parte se lleva a cabo un análisis de los diferentes factores que influyen en la adecuación de cada método. En esta última parte los métodos serán también clasificados según su adecuación a las circunstancias particulares de cada situación.

La realización de este proyecto se ha llevado a cabo principalmente a través de una investigación y búsqueda en la literatura existente en el campo de la evaluación/selección de proveedores.

A continuación se presenta un breve resumen en castellano de los diferentes métodos estudiados y de las situaciones que influyen en la elección entre estos métodos.

MÉTODOS PARA LA SELECCIÓN/EVALUACIÓN DE PROVEEDORES ESTUDIADOS.

Total cost of ownership (Coste total de propiedad).

Este método requiere la determinación de los costes más relevantes en la adquisición, recepción, uso, y el posterior reciclaje o deshecho del producto o servicio. Incluye todos los costes que afectan a la compra.

Métodos de categorización.

Estos son métodos cualitativos basados en datos históricos y en la experiencia del comprador. Se asigna un valor a cada uno de los criterios definidos para los distintos proveedores y a partir de aquí se obtiene una clasificación de estos.

Modelos de ponderación lineal.

Estos métodos cuantifican los criterios de evaluación. Los pesos relativos de cada criterio de evaluación se pueden expresar de forma numérica.

Topsis (technique for order preference by similarity to the ideal solution).

Esta propuesta trata de resolver de compensación que aparecen en los métodos anteriores eligiendo una solución a menos distancia a una solución ideal preferida y más alejada de la solución menos preferida.

Modelo Outranking.

Indica el grado de superioridad de una alternativa sobre otra, y se puede describir como una técnica parcialmente compensatoria debido al hecho de que una relativamente mala puntuación en algunos de los criterios no puede ser compensada por excelentes puntuaciones en otros criterios. Esta técnica permite especificar límites por adelantado para malas puntuaciones en uno o más criterios.

AHP.

Es un modelo para la toma de decisiones que da prioridad a alternativas cuando se tienen en cuenta varios criterios. Se estandariza el problema de decisión usando una estructura jerárquica.

Data envelopment analysis.

Este método se podría clasificar dentro de los modelos de programación matemática, porque usan esta misma para resolver el problema de decisión, pero debido a las diferencias que existen a la hora de presentar el problema se han separad en distintos apartados.

Modelos de programación matemática.

Representan la rama de las matemáticas que emplea técnicas para maximizar o minimizar una función objetivo sujeta a restricciones lineales, no lineales y enteras sobre las variables. La programación matemática permite formular el problema como una función matemática objetivo que tiene que ser maximizada o minimizada modificando los valores de las variables de la función objetivo.

Modelos de inteligencia artificial.

Las técnicas de inteligencia artificial están basadas en sistemas de ayuda informatizados programados por un experto en compras o bien usando datos históricos.

Modelos estadísticos.

Los modelos estadísticos se usan para trabajar con la incertidumbre estocástica presente en los procesos de selección/evaluación de proveedores.

FACTORES QUE INFLUENCIAN LA ADECUACIÓN DE LOS MÉTODOS DE SELECCIÓN DE PROVEEDORES

Situaciones de compra.

Compra directa o rutinaria: Productos estandarizados donde la compra se realiza automáticamente.

Recompra modificada: Se pueden encontrar los siguientes casos:

Se compra un producto nuevo a proveedores conocidos.

Se compran productos conocidos a proveedores nuevos.

Existe un nivel e incertidumbre razonable con respecto a las incertidumbres.

Nueva compra: Se pueden encontrar los siguientes casos:

Se compra un nuevo producto o servicio sin experiencia previa.

Los proveedores no son conocidos.

El nivel de incertidumbre con respecto a las especificaciones es elevado.

El problema requiere un análisis exhaustivo.

Sector de compras

El sector en el que las empresas desarrollan su actividad puede tener una gran importancia en el proceso de selección de proveedores. En este trabajo solo se ha incluido la diferenciación entre los sectores público y privado.

Diferentes tipos de productos.

Materias primas.

Bienes de producción.

Componentes.

Productos de mantenimiento, reparación y operación.

Servicios.

Tipo de relación.

Para establecer una relación proveedor comprador es necesario conocer las fortalezas y debilidades de los proveedores lo que requiere de una buena evaluación de estos. Otros criterios menos tangibles como pueden ser el grado de confianza o empatía también juegan aquí un papel importante.

Numero de proveedores disponibles.

La disponibilidad de proveedores capaces de suministrar un producto o servicio puede influir en la elección del método de selección. Si el número de proveedores que pueden cumplir las especificaciones para un determinado producto es elevado uno de los métodos que permiten una clasificación de estos sería apropiado. Por otro lado si es numero de proveedores es pequeño la principal función del método sería ordenar los proveedores con relación a los criterios establecidos por el comprador.

CONCLUSIONES OBTENIDAS.

Debido al aumento de la importancia en la selección de proveedores el número de técnicas y métodos para su ayuda también se ha visto incrementado considerablemente.

El aumento de atención sobre el proceso de selección de proveedores también se ha visto reflejado en la literatura con una importante presencia de artículos sobre el tema. La selección de proveedores es un factor clave en la estrategia de las empresas, y una decisión así requiere de un análisis de la situación específica en la que se encuentra, y es aquí donde los métodos de selección/evaluación de proveedores pueden ser de gran utilidad.

El uso de modelos de apoyo para el proceso de selección de proveedores para un mejor entendimiento y análisis del problema. Desde una perspectiva general estos métodos pueden ayudar a mejorar el proceso de decisión haciendo tener en cuenta diversos criterios, ayudar a modelar y definir la situación de una manera mas precisa o forzar al que toma la decisión a estudiar más en detalles los factores de influencia. El uso de estos métodos también puede ayudar a mejorar las habilidades del tomador de decisiones, permitir un mejor manejo de la información, como el almacenamiento de

datos para su futuro uso y estructurar situaciones de selección mejorando la comunicación.

Esta claro que la selección de proveedores no es una tarea fácil y que los métodos presentados en este trabajo puede ser una buena ayuda. Pero las técnicas descritas no son una técnica infalible que pueden ser empleadas en cualquier situación y ofreciendo una solución optima. Existe una amplia variedad de técnicas y modelos disponibles para el apoyo en el proceso de selección/evaluación de proveedores, estas técnicas presentan unas importantes variedades en cuanto a complejidad o posibles soluciones aportadas. Algunos métodos parecen ser mas adecuados para una situación en particular o presentan mayor afinidad para analizar determinados factores presentes en el proceso de compras. Los beneficios de estos métodos están condicionados por su correcta aplicación, y con esto quiero decir la aplicación de del método que mejor encaje en cada determinada situación. La eficiencia de los modelos viene marcada por completo conocimiento y comprensión de los diferentes métodos y del contexto o situación en la cual pueden ser aplicados. Las ventajas y limitaciones deben ser apreciadas y estas han de ser estudiadas bajo las características propias del problema al que se uno se enfrenta.

En este proyecto he explicado como la adecuación de diferentes métodos esta influenciada por diferentes situaciones y factores. Algunos de los modelos explicados pueden ser realmente útiles en determinadas situaciones, pero por otro lado pueden representar más un problema que una solución en otras circunstancias.

He distinguido y analizado entre diferentes factores que pueden modificar la adecuación y también la eficiencia que los métodos pueden proporcionar. Se han analizado diferentes situaciones de compras y también diferentes tipos de productos y otros factores como el sector compras también han sido mencionados.

Después del estudio de las diferentes situaciones esta clara su influencia sobre los métodos de selección/evaluación de proveedores y como la adecuación de los diferentes métodos depende de la situación en la que son usados.

Cada método presenta un número determinado de características, que de un modo u otro puede ser relacionado con una situación específica y con las características particulares a las que el que toma la decisión se enfrenta.

Como conclusión final ha tratado de presentar y describir algunos de los métodos mas empleados en el proceso de selección de proveedores. Los diferentes métodos han sido clasificados dependiendo del contexto en el que la selección tiene lugar. Esta clasificación se ha basado en la comprensión que he adquirido de los artículos leídos y donde he obtenido la descripción de los métodos presentados. Este estudio podría ser denominado mas precisamente como una descripción en profundidad de los métodos basada en las opiniones obtenidas de diferentes artículos que un clasificación, teniendo en cuenta que no se ha llevado a cabo ninguna verificación practica de los resultados obtenidos.

Teniendo en cuenta que este estudio esta basado en una investigación literaria, hacer una clasificación de los diferentes modelos para la selección de proveedores no es una tareas fácil, primero porque en la literatura en frecuente encontrarse una posición parcial por algunos de los autores, que suelen hacer una defensa de los modelos descritos en sus artículos, donde suelen defender la aplicación de sus modelos en un excesivo numero de situaciones. Segundo, tampoco es fácil encontrar en la literatura casos donde los modelos sean aplicados en situaciones reales.

STUDY AND CATEGORISATION OF MODELS TO SUPPORT THE SELECTION/EVALUATION OF SUPPLIERS

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ABSTRACT.

This project consists on a review of different methods and techniques employed as a tool to support the process of selection/evaluation of suppliers. This review was based on a literature research through relevant articles covering this topic. Based upon a group of selected articles the different methods are explained and their main advantages and shortcomings are pointing out. Within the analysis of the methods a group of different factors and situations present in the purchasing process which can affect the suitability of the methods are defined and the suitability of the methods under the particular characteristics of these situations is categorised and analysed.

This project is developed in three main parts; the first one is devoted to the explanation of general concepts and factors regarding purchasing or the purchasing function, in the second the presentation and explanation of the different method is stated. An analysis of the methods is performed, where they are compared and categorised regarding to a set of common characteristics. In the third part an analysis of different factors influencing the suitability of the presented methods is made. In this last part the methods are also categorised regarding their suitability under the particular circumstances of the defined situations.

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1. INTRODUCTION.

1.1 MOTIVATION OF THE PROJECT

The industrial sector landscape has changed completely over the last years, the globalisation of trade; shortened product life cycle and continuous technological change also call for a change into the purchasing function. The competence is worldwide, it is impossible to compete without outsourcing some of the activities performed inside the organisations; the supply chain has become global comprising different parts which can be situated in any place in the world, where the exchange of information between these different parts is essential to compete. One of the main steps to create these new supply chains is to choose the right suppliers.

The purchasing function within the organizational scheme of the companies has undergone an increasing importance over the last years. The above mentioned actual conditions call for a more strategic use of purchasing and a careful selection of the right suppliers. This increased importance and complexity of purchasing and supply management in general, and the crucial role of supplier selection decisions has also been reflected in the literature. The increase of the amount of literature published regarding the field of supplier selection methods or tools to help the decision maker to make the final choice is quite important. Many different approaches from different authors have been suggested in the recent years some of them new, others already known, trying to make its contribution to this new conception of the purchasing process, and in particular to the supplier selection process. This increase of concern in the literature is reflected in the work of some authors who have tried to give an overview of different supplier selection problems and methods [Weber et al, 1991] and [De Boer et al 2001].

As a student of Industrial Engineering, with a background in Industrial Management, this process of transformation or evolution into the industrial purchasing process can not be ignored for me. This is a matter which I find interesting to review, mainly of course for its increasing importance into the industrial sector where I hope to

develop my professional career and where my studies have been focused during these years, and also for its future evolution and development which it will be hard to understand without understanding the actual situation of the matter. The motivation of this study comes from my wish to better understand the supply chain management process in the actual scenario. Understanding the supply chain management process as “the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as whole” [Jespersen and Larsen, 2005]. This is one of the several definitions of supply chain management which can be found in the literature. But I have chosen this one because it highlights the concept of relationship or management of relationships to achieve better results. And this concept becomes really important since as I have said previously there is an important increase of activities outsourced over the last years, and consequently the selection of suppliers and management of the relationship with them are key factors here. The supplier selection process is essential to understand the supply chain management process, becoming a fundamental activity to compete, and the selection of a suitable supplier can determine the future success of the company.

I have carried this project out at the Department of Management and Engineering of the Linköping University, by researching and learning about supplier selection models, seeing what the suggested ideas are, how these are explained by different authors with the idea of reach a global understanding of the situation which can give me a proper background about this topic.

For all the reasons explained above I consider this an interesting area of knowledge where there are many ideas suggested and many others to come, which are interesting to review and which I think can help me to acquire a better understanding of the supply chain process.

1.2 PURPOSE OF THE PROJECT.

The main purpose of this project is to make a study of some of the different methods and models used as a supportive tool to the evaluation and selection of suppliers. I will classify these methods trying to place them in different groups regarding to the methodology used and their suitability for a specific selection or evaluation situations.

1.3 STRUCTURE OF THE PROJECT.

After the presentation of the motivation and the purpose of the project the structure of the work I have done is as follows:

The second chapter is devoted to explain the research methodology I have followed to develop this project.

In the third chapter the frame of reference which I have used is introduced. I am going to make the presentation and description of the different methods I have found in the literature research. I will give a view of the position of the purchasing function inside the actual organisations and how the purchasing function has evolved over the last years, explaining the main changes which have caused this evolution.

I will also describe the main strategic factors regarding the purchasing function, factors as the make or buy decision, the kind of buyer supplier relationship, and also the factors which I consider can have influence in the final choice of the supplier. This chapter is divided in four different parts, in the first, a number of factors which have influence or changed the actual purchasing scenario are explained, in the second point purchasing function is defined, the third is dedicated to explain different strategic purchasing factors, and in the last the supplier selection/ evaluation methods are presented.

In the fourth chapter an analysis of the presented methods is performed, making a comparison between them and pointing out their main advantages and weaknesses. I will also analyse the influence different factors can have to the suitability of the methods, valuing the current suitability and applicability of every approach.

In the final chapter a resume of the conclusions I have reached after carried out this project will be presented,

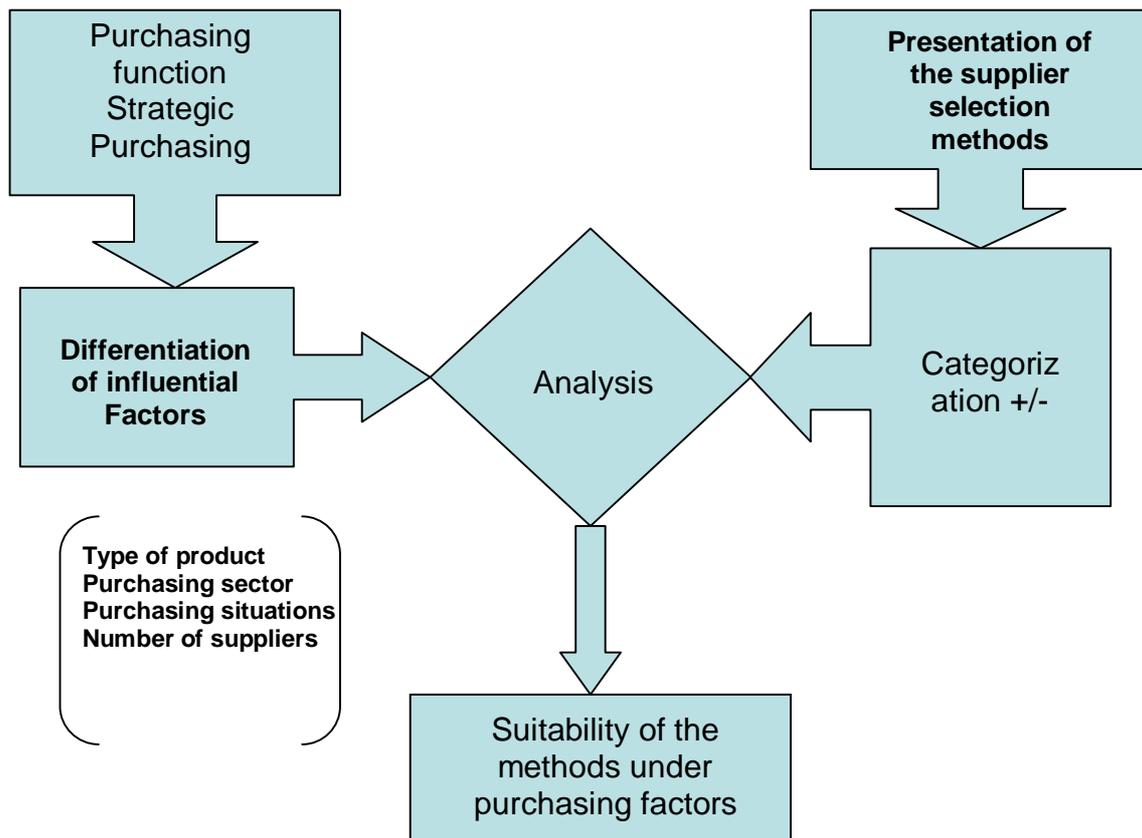


Figure1. Structure of the project

2. RESEARCH METHODOLOGY

2.1 RESEARCH APPROACH

Two choices of approach research are available the deductive approach and the inductive approach [Saunders et al. 2003]. In the deductive approach a theory based on certain hypothesis is developed and a research strategy is designed to test the hypothesis. In the inductive approach data are collected and develop a theory as a result of the data analysis.

2.2 RESEARCH STRATEGY

Once the research approach is defined, completing a successful research project depends on having a clearly defined purpose and access to useful data pertinent to that purpose [Adams and Schvaneveldt, 1991]. The various problems and eventualities present during the project require that different strategies be employed in successful research. The strategy employed, or the particular research tools involved relate to the idea known as design or research design [Adams, and Schvaneveldt 1991]. A research design refers to a plan or guide for data collection and interpretation, set of rules that enable the investigator to conceptualize and observe the problem under study. It will contain the objectives derived from the research question, specify the sources from which the data are collected and considers the constraints (access to data, time, location...).

Projects can be classified in terms of their purpose as well as by the research strategy used. A classification regarding the purpose of the project is used by Robson [1993]. He distinguishes between exploratory, descriptive and explanatory purposes:

Exploratory studies.

The exploratory studies try to look for new answers to evaluate phenomena from a new perspective. It is useful to clarify the understanding of problem. It is a flexible approach; the direction of the study can vary if new data appear. The focus of an exploratory study is initially broad and becomes progressively narrower as the research progress.

There are three main ways of conducting exploratory research [Saunders, 2003]:

Literature searching.

Talking to experts in the subject

Conducting focus group interviews.

Descriptive studies.

The descriptive studies try to provide a precise profile of the subject under study. A previous understanding of the situation is needed before the data are gathered. The conclusions are obtained from the collected data.

Explanatory studies.

The explanatory studies are those which establish causal relationships between variables to find an explanation of a situation or a problem [Saunders et al 2003]. The focus in this approach is on studying a situation with the aim to describe the relationship between variables.

In Saunders [2003] an interesting presentation of different research strategies is presented, some of them are presented here:

Experiment.

The experiment is a research strategy which tries to measure the effects of manipulates one variable on another variable.

The typical features here are selection of samples of individuals from known populations; allocations of samples to different experimental conditions; introduction of planned change on one or more variables; measurement on small number of variables; control of other variables; usually involves hypothesis testing.

Survey.

The surveys allow the collection of information in standardized form from groups of people usually by using a questionnaire, structured interviews or by observation. The typical features here are the selection of samples of individuals from known populations; collection of relatively small amount of data in standardized form from each individual.

Case study.

A case study is “a strategy for doing research which involves an empirical investigation of a particular phenomenon within its real life context using multiple sources of evidences” [Saunders, 2003]. This strategy involves a development of detailed knowledge about a single case or a small number of related cases. The typical features here are the selection of a single case of a situation, individual or group of interest, study of the case on its context and data collection [Robson, 1993]. The data collection can be made by questionnaires, interviews, observation and documentary analysis.

Grounded theory.

Here an initial theoretical framework is not required to begin with the data compilation. Several observations are performed to develop the theory and with the data obtained predictions can be created. These predictions are then tested in additional observations which can corroborate the predictions.

Action research.

This strategy research is based in three main points. The first focuses on the research purpose. The second makes reference to the participation of practitioners in the research, to a close collaboration between practitioners and researches. The third is that the research should have implications further than the actual project; this is that the results could report to other contexts.

Cross-sectional studies.

The cross-sectional studies are devoted to the study of a particular phenomenon at a particular time [Saunders, 2003]. This makes reference to that most of the research projects presents time constraints. The cross-sectional studies can try to describe the incidence of a particular trend or to compare factors in different firms.

Longitudinal studies.

The longitudinal studies are based on the capacity to study change and development. In Saunders is presented the idea that observing people or events over time the researcher can exercise a measure of control over variables under study.

2.3 RESEARCH PROBLEM.

This project will be met mainly by making a literature research through relevant articles and books related to the supplier evaluation/selection field. I will study some of the different approaches treated over the last years trying to understand them and explain them in a way that an inexpert reader could reach the basis of its working. Trying to build an opinion of what these methods can contribute to the decision makers what their advantages are and what their limitations are, what their real utility is, if their applicability is a practical fact, and in this case how these methods are used in the

decision process, or in the other hand if they are just theoretical approaches which remain in the text books and in the academic articles.

This study will not go through a specific case or method with a deep focus on it. I will give a global view of the main methods reported over the last years.

With the methods description an introduction to the purchasing function is presented, indicating the main factors involved on it

Beginning from the research approach employed in the project, this work fits better into the so called inductive approach since the conclusions are obtained after a literature review. Attending to the classification of the different research strategies presented above, this project can not be considered a survey or an experiment approach; I would place this work under the case definition, considering the case the different methods for supplier selection/evaluation within the context of the actual purchasing function situation into the organisations, obtaining the information as I have explained before by a documentary analysis.

Classifying the project regarding to its purpose, this is more a descriptive project than an exploratory or explanatory approach since it does not try to solve any problem or find the explanation to a specific situation, instead a descriptive vision of the models use to support the supplier selection process within the actual purchasing situation is presented here.

2.4 DATA COLLECTION.

As I have already mentioned one of the main parts of the project consists of a large literature research; this study is mainly based on a literature review through the different approaches concerning the supplier selection/evaluation methods treated over the last years. To gather the required information I have established an appropriate research methodology which can help me to manage an objective and reliable amount of information and also avoid a possible bias towards a particular thought or trend. This methodology consists of three basic steps: establish a searching procedure, gather the information and filter the information.

I have used for the information research the Linköping University Library resources, mainly the databases and the electronic journals but also some theoretical books. Regarding to the library databases I have used the Business Source Premier included in the field of Business and Economics and the Scopus included in the field of Engineering. Regarding the electronic journals I have used the following Journals: International Journal of Production Economics, European Journal of Purchasing and Supply Chain, European Journal of operational Research International journal of production economics... A figure of the procedure used with the sources is presented in the searching data appendix at the end of the report. The reason I have used these specific journals is that the majority of the articles I have found in the literature research in the databases were referred to these sources. Through this procedure I sought for articles from the different sources indicated which are also showed in the appendix. This searching procedure consists on trying on the browser with different key words which can help us to specified the researching and widen our scope. To find the relevant key words I tried to use those which I think best resume the aim of the project and also use words in relationship or with fields in relationship with the topic. After the first compilation an effective filter is required, to keep the most interesting and useful articles for our purpose. The words and sentences I have used are as for example: “supplier selection and supply chain”, supplier selection and supply chain and supplier evaluation”..., but all the words I have used are placed in the searching data appendix This is just a classification of the articles by an overview by reading the title or the abstract of every article and ruling out those which I consider less interesting to my purpose.

3. FRAME OF REFERENCE.

Within this chapter the frame of reference of my study is defined. This frame of reference is the theoretical base I have used to support and make clear the purposes of this project.

3.1 CHANGES IN THE BUSINESS CONTEXT.

Some of the trends which have recently impacted on the suppliers and supply base management on the procurement strategies are well reflected by Leenders and Fearon, [1997]. Following, I present these trends and some of the arguments these authors provide to explain the changes.

Globalization.

The global competition has changed the customer demands. Improved and customized products and services are now required by the customers. The sourcing of materials, products, and production capacity is not a local matter anymore. The companies look for sources of supply in every part of the world. It becomes essential for companies focus on their core activities while sourcing other activities or processes outside the organization trying to build competitive advantages.

Information technologies.

The changes produced within the information technology during the last years allow the companies to link strategies worldwide by different systems and procedures and also make the procurement process more efficient. The implementation of e-procurement systems and the use of electronic data interchange make transactions with

suppliers faster and cheaper. The internet has also increased the opportunities for electronic exchange, making easier the process of ordering and payment and has increased the opportunities for international procurement [Skjott-Larsen et al., 2007].

External customer focus.

The needs of the customers have changed tremendously. They don't buy just whatever product the firms want to sell out. They need a particular product or service to satisfy their particular needs. The companies are more conducted by the customer [Baily et al. 1998]. In this sense the companies look for integration of the supply base into the external customer product/value chain. As a result firms need at the same time look for opportunities to reduce costs and to permanently renew and innovate their products and services. The inclusion of services as after sale services, assistance or installation of the product services has become a usual practice and a part of the value offer [Van Weele, 2005]. In many cases these activities are out of the knowledge of the companies becoming the outsourcing the only option.

Product/Process technology.

Organizations need to be able to develop new procedures and products quickly and effectively. Purchasing has to be ready to help set off new ideas and developments; the new products can not be developed rapidly without a proactive purchasing function [Baily et al, 1998].

Increasing job complexity.

The purchasing managers jobs become more complex as the relationships among multiple disciplines of multiple firms are more usual and important in the purchasing process. The integration of technical and business capabilities between buyers and suppliers in the purchasing process becomes important. The collaboration on strategic planning process and research and development activities require comprehensive supply base/sourcing strategies and performance measurement to know whether the strategic goals are achieved. It is important to involve all the members in the process to know

what they are contributing in to the achievement of the goals, and also to assess their performance in the whole process.

Environmental/Legal issues.

It is required now to incorporate environmental considerations in commodity strategies; these factors have acquired a tremendous importance in the actual business. Conservation of resources, pollution and the removal and disposal of waste products are issues which firms must take into account, not just because of possible fines as consequence of the non fulfilment of legal measurements but also because of the final customer perspective of the company. The customer concern about the environment can be reflected in a preference for the type of products which are elaborated in a sustainable way.

Reengineering.

The reengineering of external processes and the modification of the outsourcing patterns, as working more collaboratively with customers and suppliers to better integrate planning and operations throughout the supply chain as a means to reduce costs and improve services is a factor which has influenced and is still influencing the procurement strategies. The integration of purchasing on engineering and production planning, involving purchasing in the early stages of the process development, to obtain benefits from the knowledge of products and markets in the product design.

Lean Supply.

The Lean Manufacturing and Just in Time ideas represent a great innovation for buyers and suppliers. The lean supply is impossible to achieve without collaboration and a combination of strategies of the suppliers and the buyer together [Lamming, 1993]. Lean supply requires collaboration and can lead to a further collaboration. The factors describing lean manufacturing include terms as quality control, inventory control, market knowledge, that are the basis for a more deeper collaboration.

3.2 PURCHASING FUNCTION

In this chapter I will present the role of the purchasing function into an industrial company. I will also define some important concepts related.

3.2.1 Position of the purchasing function.

In describing and positioning the role of the purchasing function into the industrial firms, the Porter value chain is a good point of reference [Porter 1985]. The Porter value chain is composed of value activities and the margin achieved with the activities. These activities are differentiated by Porter as primary activities and support activities.

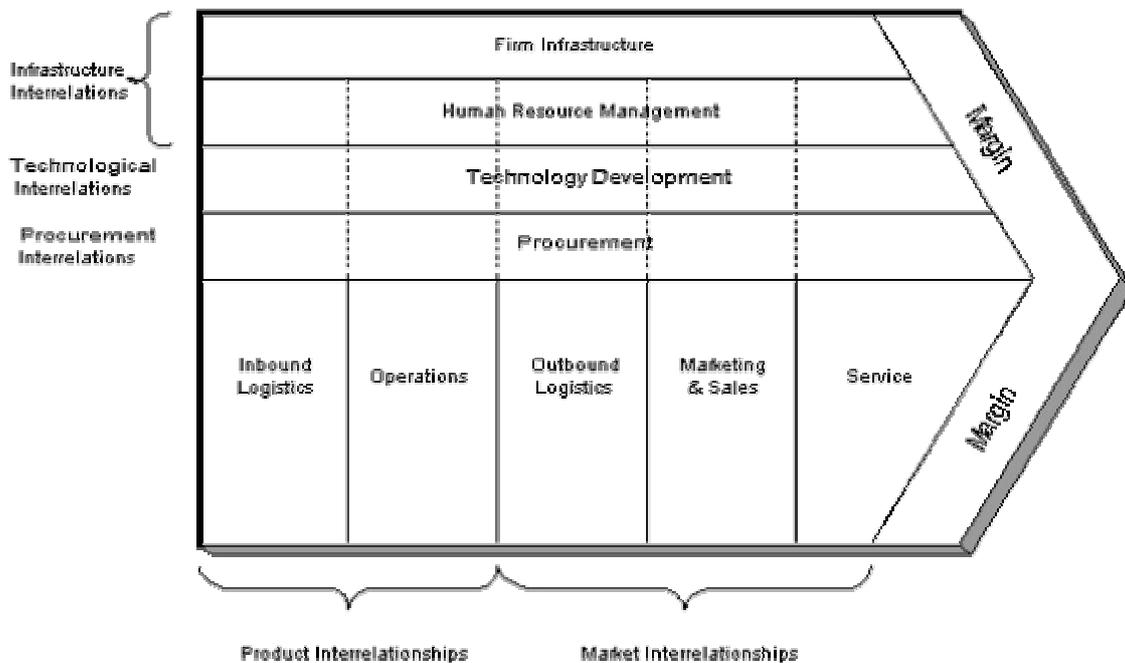


Figure1. Porter Value Chain [Porter, 1985, Google images 2008]

Primary activities are those related to the product transformation and those related to the delivery of the final products to the customers, primary activities are classified by Porter in the following manner [Van Weele, 2005]:

Inbound logistics. This makes reference to the activities concerning receiving, storing, and disseminating inputs.

Operations. Activities related to transform inputs into the final products.

Outbound logistics. Activities associated with collecting, storing and physically distributing the product to customers.

Marketing and sales. This makes reference to the sale of goods and services, promotions, sales force...

Service. Activities associated with the objective of keep the value of the product or enhance it, by providing a service as for example, a repair service, installation service...

Support activities:

The support activities are those which enable and support the primary activities and are according to Porter the following:

Procurement. Purchasing items used in the value chain.

Technology development. The technology here is the “know how”, the procedures used in the design and production.

Human resources management. Recruiting, hiring, training, developing and remuneration of personnel.

Firm infrastructure. The activities included here support all the company processes as accounting, finance, planning quality management.

Purchasing is situated by Porter as a support activity; well he uses the term of procurement instead, because he considers the purchasing term too narrow, that it is true if for purchasing is understood the process of transaction of goods.

The purchasing activity as a support activity should provide support [Van Weele, 2005] to the following activities:

Regarding to the primary activities by meeting the material requirements of inbound and outbound logistics and also operations. And also provide support to the support activities, by supplying products and services to them.

3.2.2 Purchasing function definition.

A function is defined as a department in which people use specialised knowledge skills and resources to perform specialised tasks and also what a resource is designed to do [Lysons and Farrington, 2006]. There is a distinction between the purchasing function and the purchasing department. The purchasing department is an organizational unit whose duties may include responsibilities for part of the purchasing function. The purchasing function traditionally involves the process of buying. The purchasing function covers the responsibility for the following activities [Gower, 1995]:

1. Determining the specifications of goods and services which are required.
2. Supplier selection.
3. Arriving at an agreement in terms and conditions.
4. Placing the order with the selected supplier.
5. Following the order up to ensure proper delivery.
6. After care. This includes taking care of possible claims or compiles the information obtained during the process.

A well known definition of the purchasing objectives is to purchase the right quality of material, at the right time in the right quantity from the right source, at the right price [Lysons and Farrington, 2006]

The purchasing function doesn't include activities as inventory management or material scheduling or quality control, but these material activities should be related to the purchasing process.

3.3 STRATEGIC PURCHASING.

The global changes in the operating environment of the firms: world class competition, criticality of product timing environmental objectives, price-based costing, escalating customer demands and quality calls also for a change in the traditional role that the purchasing function plays. The purchasing function needs to contribute in an effective way to the achievement of the final objectives and consequently adding value through it. This change means a more strategic use of purchasing function. And this change also means a change in the supplier buyer relationships. This is especially important if we take into account that the cost of raw materials, components parts and services purchased from external suppliers are a significant part of the expenditures for most firms. The establishment of an effective relationship between buyers and customers has acquired a remarkable importance.

In this chapter I will make a review of important situations of the purchasing process, which reference the strategic importance of it. Starting from the analysis of the make or buy decision, to the type of relationship which is more appropriate to establish and what factors should be evaluated to choose the right supplier.

3.3.1 Make or buy decision.

The purchasing process begins in an organization with the decision of whether the production of a particular product or service will be carried out inside the organization or if it will be outsourced. Outsourcing can be defined as [Van Weele, 2005] “the decision and subsequent transfer process by which activities that constitute a function, that earlier have been carried out within the company, are instead purchased from an external supplier”. This is not a trivial decision it is influenced by several factors and involves a risk exposition. It can be said that this is the first strategic question in the supply chain process.

The traditional reason for outsourcing a particular function used to be the lack of capacity to perform it. Under this question the make or buy decision is just a tactical issue, when something can not be performed in-house; someone else will have to do it. Actually there are also some new factors or quite new that are influencing the outsourcing process as they are the high labour cost level in Europe, this is causing an off shoring process to cheaper labour cost countries mainly in east Europe, India and Asia.

Under the actual competitive scenario, the companies facing the dilemma of make or buy should ask themselves one question: how can the costs devoted to add value be reduced? [Gower, 1995]. The most common answer is that all the activities except the core competences should be outsourced to a supplier which can do them at a lower cost. With the intention to reduce the gaps and release efforts to focus just on the core activities where firms can take advantages to their competitors, reduce costs and improve efficiency and effectiveness. But outsourcing just the non core activities can also limit the outsourcing possibilities too much, the outsourcing option can be also applied to the companies core activities, it is true that doing it the risks will increase and that a different kind of relationship should be established but it is also true that here the benefits of appropriate collaboration can be much bigger, and in some sectors as the automobile sector is a normal practice where almost no company manufactures all the parts of the car and in some cases the firms just assemble the different parts. I will talk more about this later on the relationship with the suppliers.

As I have said outsourcing is not an easy decision, an inappropriate allocation of work to a supplier can cause important problems for the organization. There are many risks involved as loss of control, loss of critical skills, loss of intellectual property, loss

of security, service quality drops, and increase in cost and loss of innovative power [Van Weele, 2005]. In the analysis of the make or buy question several factors have to be studied and asses, factors as the investments on resources available for the production, the abilities developed by the firm in products and processes and an evaluation of the possible suppliers. It is not enough to obtain the costs and prices which the outsourcing of a product or service would involve in order to compare with the in-house performance and calculate the added value. This is also a main problem to know how much value was added by the outsourcing process and at what cost. Here regarding to this problem is also introduced the type of relationship to establish with the suppliers, if a developed relationship take place it should be easier to provide a value/cost data. It is normal to think that in a more close relationship the interchange of information and the mutual knowledge of each other will be higher.

When the decision of outsourcing has been taken, the purchasing process has begun and several factors must be taken into account. The number of suppliers the firm wants to work with, the kind of relationship that is pretended to establish, the kind of product or service is going to be outsourced.

3.3.2 Relationship with the suppliers.

Traditionally the characteristics which define the relationship between buyers and suppliers have been short term and adversarial, where the changes of suppliers were usual. The development of a strategic role for the purchasing process and the changes in manufacturing strategy, induced by the lean manufacturing and just in time concepts, makes companies become aware that a full cooperation with the suppliers can lead the firm to a cost reduction, quality improvement and lead time reduction [Lamming, 1993]. An establishment of a partnership where both parties work together from the first stages of the product conception and a fluent interchange of information is required, looking for a long term strategy where the benefits will not be reached immediately. But there is not a perfect model of relationship to apply in every situation, this is influenced by different factors and situations and the traditional model and as well the partnership relationship model can be perfectly used depending on the situation.

3.3.2.1 Factors for analyzing buyer supplier relationships.

Many different factors can influence the buyer supplier relationship; I could say that there are as many factors as different cases or situations exist. Here I show some factors that Lamming [1993] proposes as a framework for analysing relationships between buyers and suppliers. The influential factors he found and what I introduce here were taken from several interviews to analyse the relationship between an automotive assembler and its components suppliers, but those factors can also be exported to the analysis of a relationship in others different sectors.

The factors considered by Lamming are the following:

The nature of competition. The nature of the competition in the components required influence the relationships between the buyers and the components providers, if there exists a competency to obtain the lowest price products the relationship established with the suppliers will not be the same if the competency is based on obtain technological improvements.

The basis upon which sourcing decisions are made. The manner in which the suppliers are selected clearly influences the future relationship, the option of bids coupled with the lowest price choice doesn't look like a future partnership; instead a conscious evaluation of feasible suppliers can be understood as the first step of a deeper relationship.

The role played by data and information transfer. The relationship is affected by the grade and the quality of communication between parts. The grade of communication makes reference to the fluency the communication takes place with, this is related to the technology employed, as for example electronic systems to the data interchange. And the quality of information means if the shared information is reliable, if none hide information to trying to use it to take advantage from the other part, here it is introduced the concept of mutual trust which I will explain in advance.

The attitude to capacity planning, and the approach towards managing it jointly. The capacity planning has a strategic importance: investment in appropriate new plant or assets.

Delivery practices. The development of a just in time delivery rather than an imposition of the buyer's demands it could be a good point to assess the closeness of the relationship.

The manner in which price changes are dealt with. In the traditional approach negotiation and confrontation have been the main characteristics. But this practise is not appropriate for long-term relationships, where a continuous pressure forcing the supplier to reduce prices would lead to a poor supply and higher real costs.

The attitude towards product quality. This factor has changed from the traditional inspection techniques to share of responsibilities for the quality requirements achievement.

3.3.2.2 Models of relationship.

The two most referred models in the literature are the adversarial corresponding with the traditional approach of purchasing and the partnership model. These two models reflect the two ends of the relationships which can be established between buyer and supplier. Sako [1992] made a study of the relationships between Japanese and British firms and present two ending models of relationships where in between them all the possible types of relationships would be included. These two models are:

1. Arm's-length contractual relation (ACR).
2. Obligational contractual relation (OCR).

The ACR relation involves a specific economic transaction. A detailed contract is signed to set all the tasks and duties from both parts and reflect the procedure to follow if possible problems arise. The relationship is just drive for the legal issues reflected in

the contract and when the relation ends it is normal to contract another supplier. This relation is characterised by a low degree of independency, and an immediately reciprocity is expected within the contract duration.

The OCR relation includes an economic contract as well, but it is involve in more specific social relations between parts which involves the concept of mutual trust. The inclusion of this term in the relationship makes that not all the transactions take place under a previous agreement or contract. There is an incentive to outperform the tasks fixed, not just to do what is expected and this is reflected in both parts. In this case the mutual trust cause a high degree of interdependency, there is a moral commitment of maintains the relationship, which involves a preferential treatment and proper use of the shared information, an understanding of the respective requirements and providing assistance to each other.

The trust involved in the OCR relation is named by Sako [1992] *goodwill trust* and is differentiated by her from the *contractual trust* (both parties keep their promises) and *competence trust* (both partners can perform their role competently) which are included into the ACR relation.

These models are not presented by Sato as a dichotomy, instead a continuum of several trading patterns, so a relationship can be as more OCR or ACR depending of where the characteristics of the relation are situated.

Another way in considering types of relationships is to identify exchange situations [Saunders, 1994] Saunders differentiates between two main types of exchange situations: Market/competitive situations and Partnerships.

In the Market/competitive situations the relationship between parts is based on a previous formal agreement normally reflected in a contract. The contract used to be periodical and all the main issues as prices, orders or rebates are reflected on it. The products involved in this kind of exchange used to be standardised and the differences with the products offered by the others suppliers are minimal, and when the agreement finish, it is not a problem to shift to another supplier. The relationships involved in this situation are usually not long and the communication is limited where a real integration between parts doesn't exist.

A definition of partnership provided by Partnership Sourcing Ltd and included in Saunders [1994]:

“Partnership sourcing is a commitment by both customers and suppliers, regardless of size, to a long-term relationship based on clear, mutually-agreed objectives to strive for world-class capability and competitiveness”.

The products or services exchanged in this situation are tailored and developed under specific characteristics, this involves a fluent relationship where both parts need to work together and interchange information. The prices and transaction costs are reduced mainly thanks to putting the supplier’s competences and knowledge to better use. The change of supplier in this situation is difficult because of the exclusivity of the relationship and the high switching costs. This kind of relationships involves a long term commitment by both parts to reach the goals established.

I have presented here two different forms of considering relationships between buyer and supplier, but as we can see in the above description both have many points in common. The most important of these coincidences is the existence of relationships based on mutual commitment or trust, these types of relationships (partnership or obligational contractual relationship) which go beyond the transaction or the interchange of goods. The aim of these trust based relationships is searching for a more sophisticated way of relationship where an establishment of common objectives and mutual collaboration is required. These types of relationships are considered by the majority of the authors and are implemented in many organisations as a way to improve their supply chain process.

3.3.2.3 N° of suppliers.

The number of suppliers that firms decide to work with is a strategic question which depends on many different factors. This is a question deeply related to the relationship model established. It is true that over the last years many companies have reduced the number of suppliers trying to build closer relationships and that a

multisourcing approach seems to be more appropriate for a traditional short term and transactional relationship. But it doesn't mean that this is the right way to follow and that every company should go to a supplier reduction.

There are many different reasons why a firm prefers to work with a reduced number of suppliers or with an exclusive one. One company may prefer work with an exclusive provider trying to reach a cost reduction because of the economies of scale, or trying to obtain a time to market reduction or product development, but on the other side there are some problems in the reliance of a reduced number of suppliers, as the excessive dependency of one source or the lack of motivation induced for the absence of competition. Some companies prefer to work with several suppliers which can ensure the supply and also offer a set of alternatives to shift. It exists also the risk of lack of know-how and capabilities which can cause a lock-in with the supplier.

3.3.4 What to evaluate.

There is not doubt about the multi-criteria nature of vendor selection. Quality, price and delivery are the criteria traditionally used, but to establish a long term relationship based in partnership other criteria are also required and some of these criteria are less tangible issues, as trust innovation efforts or the grade of commitment with the firms strategy.

Strategic management decisions affect the importance of criteria in the supplier selection process. The implementation of the ideas of the manufacturing Just- In-Time strategy together with all the business changes commented above have also contributed to the change of some of the criteria used to evaluate.

But the most important change as a result of the other commented changes is the strategic orientation of the purchasing function, the length and the character of the relationship, the number of suppliers to work with...

Different articles in the literature describe criteria which must be evaluated for the selection of the appropriate supplier. But the criteria to asses are not something you can translate to every situation they depend on the particular situation, but as Lysons and

Farrington [2006] say all the potential suppliers should be evaluated from eight perspectives:

1. Finance.
2. Production capacity and facilities.
3. Human resources.
4. Quality.
5. Performance.
6. Environmental and ethical considerations.
7. IT.
8. Organisational Structure.

The methods for supplier evaluation presented in this project try to measure and value these different criteria as a support for the supplier selection, and I will try to establish a relationship between the models presented, which are some of the most typical approaches covered in the literature, and some factors which influence the purchasing process.

I have presented here four strategic factors, the make or buy decision, the type of relationship, the number of suppliers and criteria which should be evaluated to choose the right supplier. These are general factors which have to be taken into account into the purchasing process, and which have been described in a theoretical and general way. But link the methods to supplier selection with these factors is difficult because of their general perspective, with this I mean that they have been explained in a very general way. To categorise the methods and to link them with the strategic factors explained I will use the context where the purchase takes place. The context of the purchase makes reference to aspects as the type of product which is pretended to buy; the situation where the purchase takes place or the sector the organisations is involved in. Under the different contexts the type of relationship to establish, the number of supplier available and the factor to evaluate can be better specified. In order to find a number of factors which can be related to the supplier selection methods and used to make a categorisation of them based on their suitability under the influence of this factors I have chosen the following.

1. Purchasing situation.
2. Purchasing sector.
3. Different kind of products.
4. Type of relationship.
5. Number of suppliers available.

All these factors will be introduced and explained their connections with the presented methods in the chapter four.

3.4 DESCRIPTION OF METHODS FOR SUPPLIERS SELECTION/EVALUATION.

Within this chapter it is pretended to show a resume of the different models and techniques used nowadays as a tool to support in the supplier selection process. With the growing importance and the professionalization of the purchasing decision making, it is clear that the number of methods treated in the literature and the coverage of them is consequently broader, as it can be see with the existence of articles giving an overview of different supplier selection methods and also in a more extend presence of new methods and approaches in the most recent articles. A brief description of each model will be presented and also a view of the different evolutions or approaches followed by different authors within these models is tried to be presented.

Some authors divide the supplier selection process in four different phases [De Boer et all (2001)]: problem definition, formulation of criteria, qualification of suitable supplier and final selection.

Decision methods for problem definition are methods that support the decision maker in questioning the need for a decision and the alternatives that seem to be available, as determining what the ultimate problem is and if it is better select one or more suppliers.

In the phase of formulation of criteria the main tasks for buying firms is assessing the key competitive factors in their industry or sector and translating these dimensions into supplier selection criteria. The choice and the number of criteria to be included in the supplier selection process must be carefully determined to represent the competitive strategies of the buying firms.

I have not found any article in the literature that treats the stages of problem definition and formulation of criteria, so my study is just limited to methods applicable to the qualification of suitable supplier and the final selection phases.

Qualification of suitable suppliers is the process of reducing the set of all suppliers to a smaller set of acceptable suppliers. This is a sorting process rather than a ranking process.

The main part of the methods suggested in the literature applies to the final selection phase of the supplier selection phase, but some of them are also suitable for the third phase, the qualification of suitable suppliers, allowing a reduction of the initial set of suppliers available. I will explain this further during this chapter. These methods which I am going to present here are used as a support tool in the supplier selection process in the phases of qualification of suitable supplier and in the final selection phase. They can be classified in three big categories or groups [Araz and Ozkaram 2005]: mathematical programming models, rating/linear weighting models and artificial intelligence techniques, but there are some other models I will also present here.

3.4.1 Total cost of ownership

Following the definition given by [Ellram and Siferd, 1998] the TCO (total cost of ownership) approach is a purchasing tool and philosophy aimed at understanding the relevant cost of buying a particular good or service from a particular supplier. This is a model that requires the buying firm to determine which costs it considers most relevant in the acquisition, possession, use, and following disposition of a good or service, the TCO approach looks beyond the price of buy, including all the costs affecting the purchase. This model aims to analyse all the costs incurred through the value chain of the firm associated with the purchasing process. A distinction in this purchasing process can be made between: pre-transaction, transaction and post-transaction costs [Ellram, 1995]. In the pre-transaction costs can be included a quality audit or costs devoted to researching about some product or supplier, in the transaction costs includes costs as order placement, cost related with reception and invoicing or transportation, in the post-transaction cost are included warehousing costs or cost related to defective deliveries [Degraeve et al 2000]. The process begins with the statement of the most relevant factors in the purchase and then these factors are converted into cost components which are added to a price formula. After that to each supplier assigned price is associated a debit or credit for every factor according to their performance. The lower the total cost is the best the supplier chances are to be selected.

The models traditionally used, consider just the price as the decision factor, this TCO model propose an change in this conception, here is where the word “philosophy” included in the Ellram definition makes sense, the total cost of ownership proposes a cultural change in the organization, a change of mentality from a price oriented culture to a cost oriented understanding.

The theoretical basis of the TCO analysis is on the transaction costs. The analysis of these costs have been mainly applied to the make or buy decision, but the TCO analysis can also be applied once the company has decided to outsource one process. The transaction costs can vary significantly from one supplier to another, so they can be used as a decision factor. The analysis of the purchasing costs throughout the supply chain permits to analyse different activities and determine the cost drivers for this activities, helping to find several factors which increase costs. This analysis is called Activity based costing (ABC) which permits to analyse activities and identify the different cost drivers for the defined activities.

Activity based costing is a management accounting technique which attempts assign costs to cost generating activities within a business Degraeve and Roodhooft [1999]. This technique uses activity analysis, which defines the different activities performed by the company.

The total cost of ownership philosophy can be described in the following steps: first define the activities based on the external purchasing and assign cost to every activity. The next step consists in find the cost drivers. These are the factors which raise the cost of one activity. And the last the activities generated by the purchasing organization must be identified by each individual supplier.

3.4.1.1 Strengths and limitations.

One of the main strengths of this approach is that provides a clear quantitative evaluation tool of different suppliers and doing it in a long term measurement which permit obtain an over time evaluation. The analysis of the purchasing cost make possible to find some costs which otherwise would stay hidden, or which is usual not to pay attention to. The trade-off between criteria is not a problem because the objective

function is defined as the TCO of the purchasing decision caused by the suppliers. Another advantage is the systematic way in which it can be performed. [Khurruum and Faizul, 2002]. The TCO provides a source of data which can be used in the negotiations, and also to develop interorganizational relationships between the purchaser and the suppliers.

One of the main problems to the application of this model is the effort required to make the analysis and the need of a system to gather the accounting and costing data. It is hard to gather all the information without an efficient system, which use to be a computerized system; this can be a problem mainly for small and medium companies where these systems can result excessive expensive [Khurruum and Faizu, 2002]. Another limitation of this model is that there is not a general formula applicable, the TCO model used are different from one company to another, and also in the same company depending on the kind of buy, it also has difficulties to valuate the intangible qualities, in this case there are some approaches which combine rating systems with the total cost [Monczka and Trecha (1998)], [Smytka and Clemens (1993)]. Another factor which limits this approach is that the costs are specifics of every different situation.

3.4.2 Categorical method.

Categorical methods are qualitative models based on historical data and the buyer's experience current or familiar suppliers are evaluated on a set of criteria [De Boer et al. 2001]. This is probably the simplest approach, which assigns either good (+), neutral (0) or unsatisfactory (-) to each defined criteria for all suppliers, and then a total rate for each supplier is calculated.

3.4.2.1 Strengths and limitations

This approach depends heavily on the human judgments and also weight the criteria equally which rarely happens in practice [Zenz, 1994].

This method is clearly not broader treated in the literature because of its simplicity and lack of objectivity is not in accordance with the actual growing importance of the supplier selection.

3.4.3 Linear weighting models.

The models based on linear weighing works assigning weights the different criteria taken into account, the biggest weight indicating the highest importance. Ratings on the criteria are multiplied by their weights and summed in order to obtain a single punctuation for each supplier [De Boer et al 2001].

Using linear methods a compensation problem between the different evaluations can take place; a good performance in one criterion can balance a poor one on another, and this is not realistic in most cases.

3.4.3.1 The Weighted-point method

The weighted point method quantifies the evaluation criteria. A number of evaluation factors can be included, and their relative weights can be expressed in numerical terms so that a composite performance index can be determined and supplier comparisons made [Zenz, 1994].

$$V(A_i) = \sum_{j=1}^n W_j \cdot X_{ij}; (i = 1 \dots n)$$

Where W_j is the weigh of each criterion and X_{ij} is the punctuation of every criterion for each different supplier evaluated.

3.4.3.1.1 Strengths and limitations

This is probably the most known method and maybe still one of the most used mainly because of its easiness of implementation and understanding. But it presents some problems which make its application less appropriate for a rigorous selection. One of the problems of the weighted models is that it is required to normalize the different punctuation of each criterion, to avoid problems caused by the comparison of criteria with different units, in a way that each value can be established in a no dimensional unit.

The main problem of this model is as I have said before the compensation between different criteria a high rating on one criterion can compensate a low rating on another criterion, some approaches as the outranking method try to solve this problem by establishing specified limits over the different criteria, and I will explain this in more detail later. The method makes the supposition that the criteria are independent to the decision maker, this is that the contribution of each individual criterion to the final punctuation is independent from the values of the other criteria. This makes the personal opinion of one decision maker more influential.

3.4.3.2 Topsis (technique for order preference by similarity to the ideal solution)

The Topsis approach can be considered as an evolution of the Weighted-point method. This approach tries to solve the compensatory problems of the previous method by choosing a solution with less distance to an ideal preferred solution and more away from the less preferred solution.

The concept of Topsis is that the most preferred alternative should not only have the shortest distance from the positive ideal solution, but should also be farthest from the negative ideal solution [Shih, 2008]. Topsis simultaneously takes into account the distances to both the positive ideal solution and the negative ideal solution and a preference order is ranked by the composite distances.

An ideal solution is defined as those that reach the highest punctuations in all the factors considered, even if this solution can not be reached.

Normally the nearest solution to positive ideal is not the farthest to the negative ideal.

The Topsis method follows the following steps [Ahi et al.2008]:

1. Obtain the normalized values (n_{ij}) of the punctuations the normalization is made by the following transformation for each r_{ij} :

$$n_{ij} = \frac{r_{ij}}{\sqrt{\sum_{i=1}^m r_{ij}^2}}, (i = 1 \dots m; j = 1 \dots n)$$

2. Obtain the weighted normalized values:

$$V_{ij} = W_j \times n_{ij}; (i = 1 \dots m, j = 1 \dots n)$$

where W_j represents the weight of j th criterion

3. Identify the both solutions the ideal positive and the ideal negative of all the criteria.

$$A^+ = (V1^* \dots Vj^* \dots Vn^*)$$

$$A^- = (V1^- \dots Vj^- \dots Vn^-)$$

4. Obtain the distance of each alternative with the ideal positive and the ideal negative solutions. Two Euclidean distances for each alternative are calculated as follows:

$$S_i^+ = \sqrt{\sum_{j=1}^n (V_{ij} - v_j^*)^2}; (i = 1..m)$$

$$S_i^- = \sqrt{\sum_{j=1}^n (V_{ij} - v_j^-)^2}; (i = 1..m)$$

Where S_i^+ and S_i^- represents the distance of alternative A_i from the positive and negative ideal solutions, respectively.

5. Calculate the similarity to the ideal positive solution:

$$RC_i = \frac{S_i^-}{S_i^- + S_i^*}; (i = 1..m)$$

$$0 \leq RC_i \leq 1$$

Normally the nearest solution to the ideal positive solution is not the same as the farthest to the ideal negative solution, this is the reason because is necessary to define a similarity index (RC) combining the proximity to the ideal positive solution and the distance to the ideal negative solution.

6. Ranking the alternatives: Alternatives are ranked based on RC_i in which the highest score is the best alternative.

Classify the alternatives in a decreasing order of RC_i . The best supplier will be the one with the higher value of RC_i what means which is the solution most far away from the worst possible solution.

3.4.3.2 .1 Strengths and limitations

This method still has the problem of the necessity to provide quantitative values by the decision makers represented by weights.

The Topsis method has been an important tool used in the decision making field, but it is not wide found in the literature regarding the supplier selection problem mainly because it does not provide a weight elicitation, and a consistency checking for judgements. This method uses some mathematical procedures to solve the compensatory problem and to obtain a solution with more dependency on all the criteria, but the basis of the model is not that much different from those of the weighted-point method. The system of assignment of the weights is the same and it shows a lack of knowledge of the global situation, the analysis of different influent factors in the purchasing situation here is not applicable. So I think this is an improved version of the weighted-point method, but almost present the same problems.

There is not much literature written about topsis method as a tool to supporting tool to supplier selection [Cheng et al 2007] published a study with a hierarchical fuzzy Topsis approach. The term fuzzy makes reference to deal with the uncertainty and imprecision into the supplier selection problem.

3.4.4 The Outranking approach

The outranking approach indicates the degree of dominance of one alternative over another and it can be described as a partially compensatory technique due to the fact that a relatively bad score on some criterion can not be compensated for by excellent scores on other criteria. This approach allows the buyer to in advance specify limits to the compensation for bad scores on one or more criteria.

Referring to the outranking relations the following definition [Dulmin and Mininno, 2003] is stated:

“an outranking is a binary relation S defined on A , such that aSb (a outranks b) if, given what is known about the decision maker’s preferences and given the quality of the evaluations of actions and the nature of the problem, there are enough arguments to decide that a is at least as good as b , while there are no essential reasons to refuse that statement”.

Nowadays there are three classes of outranking methods [De Boer et al, 1998] Electre [De Boer et al, 1998], Promethee [Dulmin and Mininno 2003] and Oreste [De Boer et al, 1998]. I just will introduce here one of these models the Electre, it is the first outranking method developed and it gives a good notion of the ideas which are behind the outranking approach. Other outranking methods are more advanced as they accept differences in the strength of the decision maker’s preferences as well as the possibility of the decision maker being indifferent with respect to two alternatives. But I will not discuss here the details and technicalities of specific variants of the methods.

If we look at the definition of the outranking relations I showed above [Dulmin and Mininno 2003] this takes into consideration that the different effects of the alternatives are not totally known, that the definition of the problem might not be exact and that the preferences of the decision maker are not entirely known and contradictory to a certain level.

The explanation of the Electre methodology is as follows [De Boer et al, 1998]: Assuming that a set of alternatives A and a set G of n criteria are given. The alternatives are represented by the following letters a, b, c, \dots and the criteria by $g_j, j=1, \dots, n$. So $g_j(a)$ represents the score of alternative a on the j th criterion.

The main point here is to put together the different punctuations of each criterion into an overall punctuation for the alternative. To do that the user needs information about the relative importance between the various criteria. For every criterion j a weight k_j is set. But as it's been said before, the decision maker can establish limits for the acceptability of a particular alternative and a score under the determined limit in one alternative on a particular criterion can make it unacceptable for a decision maker despite the alternative shows higher scores in the other criteria. In order to establish this limits the decision maker has to decide for which combination of alternatives outranking of alternatives b by alternative a is unaccepted regarding a bad score of a on a particular criterion relative to the score of b and without take into account the scores of both alternatives on other criteria. This is called by De Boer the discordance sets.

Once the weights and discordance sets have been established, a concordance index for any a and b alternatives $conc(a,b)$ is calculated. With this concordance index the grade of preference of the decision maker for a above the b is showed. In this case, in other words the main pros in favour of the assertion a outranks b . This grade of preference is obtained by the sum of the weights of the criteria on which alternative a scores at least as good as alternative b . After that, the next step consists on establish a concordance threshold in a way that if the concordance index for two alternatives is higher than the concordance threshold established, the assertion "a outranks b" is considered true. Thus the affirmation that "a outranks b" is based on if two conditions which must to be met. First $conc(a,b)$ has to exceed the threshold value and second the value of a should not be much worse with respect to b on a certain criterion which prohibits outranking of b by a .

3.4.4 .1 Strengths and limitations.

The advantages of this approach are its suitability to work qualitative and quantitative criteria managing the compensatory effects [De Boer et al, 1998]. The definition of the criteria and their weights, the discordance sets and the concordance threshold make a better understanding of the purchasing situation than the previous approaches and also they can help to deal with factors as uncertainty thanks mainly to

the determined thresholds. What I am saying here is that this approach requires more considerations to establish the buyer preferences and requires him to think about these aspects which give more flexibility to the model since include other factors as personal experience or opinions. The normalization of the decision matrix is not required to handle the different types of attributes which can handle ordinal or descriptive information. Electre differs from the other methods in that it doesn't provide a global preference of alternatives but a partial ranking of alternatives. This factor could be useful for a possible comparison with other methods.

The main limitation of the outranking methods is the difficult interpretation of the results it based upon factors which require a subjective interpretation of the situation and it is not easy to understand for an outside of the decision maker perspective. Also this means that is a very subjective approach which a strong dependency on the decision maker opinions.

3.4.5 AHP model.

The Analytic Hierarchy Process is a decision-making method for prioritizing alternatives when multiple criteria must be considered. It has been used successfully in many situations, but here I am just going to speak about the model regarding to the supplier selection.

The AHP method was developed by Saaty in 1980 [Saaty, 1994] this involves the standardization of a complex decision problem by the use of a hierarchical structure. It begins from a visual representation of the multicriteria problem building a hierarchy with the attributes used to make the decision. This hierarchy comprises normally three levels: the global objective in the higher level, the criteria which define the different alternatives in the intermediate level, and the alternatives the decision maker has to choose from in the lower level. The global problem is to choose the best supplier; the basic criteria can be used as the most typical: quality, price, service and delivery time, and the alternatives are the different suppliers between the selections can be made.

The process begins by setting the relative importance between the different criteria to reach the final objective. After this, the process treats the way in which the alternatives satisfy every criterion and finally the results of both analyses are put together to obtain the relative importance of the alternatives to reach the global objective.

The attitude and judgments of the decision makers drives the model. These attitudes are reflected in terms of pairwise comparisons of items on a given level of the hierarchy with respect to their impact on the next higher level. Pairwise comparisons express the relative importance of one item versus another in meeting a goal or a criterion. Each of the pairwise comparisons represents an estimate of the ratio of the weights of the two criteria being compared. The AHP is a flexible tool that can accommodate a larger set of evaluation criteria. For example, related criteria can be grouped into the most typical categories such as quality, price, delivery, and service. These categories can be compared pairwise first, and then the individual criteria can be pairwise compared within each category. In this way, a larger number of criteria can be included within the hierarchy without generating an extremely large pairwise comparison matrix.

Since this method allows the use of qualitative criteria, different scales can be used to transform the decision makers thoughts into a number, the scale used by Saaty, shown in Table I [Nydick and Hill, 1992] is the standard used.

Verbal judgment or preference	Numerical rating
Extremely preferred	9
Very strongly preferred	7
Strongly preferred	5
Moderately preferred	3
Equally preferred	1

The intermediate values of 2, 4, 6, and 8 provide additional levels of discrimination.

The pairwise comparison for each member of the problem is represented by a pairwise matrix. If there are n supplier to compare then $n(n-1)/2$ judgements are needed and there are n^2 cells in the complete matrix [Nydick and Hill, 1992]. There are two reasons

for this number of judgements. First any alternative is equally preferred to itself, and then the diagonal of the matrix is filled with ones. Second, the positions below the diagonals are reciprocals of the judgments already entered. To make this more clear an easy example of a pairwise matrix is presented:

	Quality	Price	Service	Delivery time
Quality	1	2	4	3
Price	1/2	1	3	3
Service	1/4	1/3	1	2
Delivery time	1/3	1/3	1/2	1
TOTAL	25/12	11/3	17/2	9

The AHP algorithm consists of the following steps [Nydick and Hill, 1992]:

1. Specify the criteria to evaluate the suppliers.
2. Obtain the comparisons between the criteria regarding to the relative importance to reach the goal and calculate the weights by means of this comparisons.
3. Obtain measurements which describe the behaviour of every supplier in every criterion.
4. With the information in the step three obtain the comparisons of the relative importance of every supplier regarding to the criteria and calculate the priorities.
5. Using the results of the steps three and four, obtain the priorities of every supplier to reach the global goal.

3.4.5.1 Strengths and limitations.

This model tries to solve the problems of having to provide exact estimations for criteria weights as well as performance scores in the basic linear weighting model. With the AHP model the decision makers just need to give a qualitative statement regarding the relative importance from one criterion to another, and the same with respect to the

suppliers regarding to the criterion. Other advantages of the AHP approach [Muralidharan et al., 2002] are its ability to structure the problem in a hierarchical way to gain insights into the decision making process making the process more transparent for the users and its ability to monitor the consistency with which a decision maker makes judgment.

It is a quite flexible model, a sensitivity analysis could be done without spending much effort, and also easy to adapt to the possible changes of the criteria.

The limitation of the AHP model is that results are dependent on the subjective judgements of the decision makers. Decision makers have to specify not only the direction of relative importance (Criterion A is more important than criterion B) but also the degree of relativity. The requirement of user preference is too demanding, when implementing these models. Another limitation can be that this is not a straight forward model and it can make the process cumbersome to use for many users, and also an important amount of information is required to compare all the alternatives which can be difficult to obtain [Chan, 2003].

3.4.6 Data envelopment analysis.

This approach could be included into the mathematical programming models, because it use mathematical programming to solve the problem presented but I decided to not include it in because of the differences with the mathematical approaches on the manner to present the problem.

The DEA model based articles I have founded in the literature are mainly based on the work carried out by Charnes [Weber and Desai. 1996]. The DEA approach is a multi-factor analysis tool that measures the relative efficiencies of a set of decision-making units. It considers multiple input and output factors in evaluating the efficiency scores [Talluri and Narasimham, 2004]. These input and output factors are here the supplier's capabilities and performance. DEA is based on the concept of efficiency; this concept in the context of supplier selection/evaluation refers to the amount of resources required by one supplier to supply one unit of the item or a service required. The efficiency concept is used to distinguish between efficient and inefficient suppliers, so one vendor is

considered efficient if there exists no other vendor or some combination of other vendors, who can deliver at least the same quantity or the same service with less resources (less price, less tardiness, etc.) and consequently if there is another supplier able to perform the same activity using less resources it becomes an inefficient supplier. The DEA approach finds the most favourable set of weights for each supplier, that is the weights that maximises the supplier's efficiency score, and limiting at the same time its own rate and the rate of any supplier to one [De Boer et al. , 2001]. It does not require the decision maker to predefine the weights these are endogenously determined when solving a DEA model. DEA can automatically derive optimal weights of criteria with the performance scores of the suppliers. In this way the DEA method helps the decision maker to classify the vendors between efficient and inefficient. The weights of the involved inputs and outputs are obtained as the optimal solution of the DEA model. There are different models based on DEA approach treated in the literature but I will just present two of them to show how this approach works. These models are the CCR DEA model and the cross efficiency models [Talluri and Narasimham, 2004].

CCR model.

In the CCR model the efficiency measure utilized in DEA is defined by the following equation:

$$E_{ks} = \frac{\sum_y O_{sy} v_{ky}}{\sum_x I_{sx} u_{kx}}$$

Where the E_{ks} is the efficiency of productivity measure of supplier s, using the weights of test supplier k; O_{sy} is the value of output y for suppliers s; I_{sx} is the value for input x of supplier s; v_{ky} is the weight given to supplier k for output y; and U_{kx} is the weight given to supplier k for input x.

In the ratio DEA proposed by Charnes [Weber and Desai. 1996] known with the name of CCR each test supplier chooses optimal weights for capabilities and performance metrics to obtain the highest score in the efficiency equation, taking into account the constraints that these weights avoid the supplier to obtain an efficiency score higher than 1. This CCR model is presented as follows [Talluri and Narasimham, 2004]:

$$\text{Maximize } E_{kk} = \frac{\sum_y O_{ky} v_{ky}}{\sum_x I_{kx} u_{kx}}$$

Subject to: $E_{ks} \leq 1 \forall$ Supplier s

$$u_{kx}, v_{ky} \geq 0$$

The conversion into a linear programming problem is:

$$\text{Maximize } E_{kk} = \sum_y O_{ky} v_{ky}$$

Subject to: $E_{ks} \leq 1 \forall$ Supplier s

$$u_{kx}, v_{ky} \geq 0$$

$$\sum_x I_{kx} u_{kx} = 1$$

The denominator of the efficiency equation is equalized to 1 by the constraint $\sum_x I_{kx} u_{kx} = 1$;

The result of the linear programming model is an optimal efficiency score E_{kk}^* which a value never higher than 1. A supplier is efficient just if $E_{kk}^* = 1$ and the others variables

are 0, if $E_{kk}^* \leq 1$ then the supplier is considered not efficient because it is dominated by other supplier or by a linear combination of suppliers. In order to obtain the efficiency scores of all the suppliers this problem is accomplished s times.

This model allows complete flexibility in the choice of weights, which may lead some units to be assessed their efficiency with reference to a set of unrealistic weights. As for example only a few weights are non-zero which means that the unit under analysis is being assessed on a small subset of input and outputs. For example an optimal solution with several zero weights could indicate that this unit is just exploiting the weight flexibility to appear efficient, when it would be possible to find another solution with not zero weights.

Cross efficiency models:

These models are mainly used to solve the problem of the unrestricted weight flexibility. The CCR model permits to give emphasis to a few inputs and outputs without taking into account others factor to obtain a higher efficiency. With the cross efficiency model and the cross efficiency matrix (CEM) the information obtained includes the optimal weighting schemes determined by other suppliers. In the CEM the elements in the k th row represent the efficiency of supplier s when is assessed against the optimal weights of supplier k (E_{ks}). Each of the columns is averaged in order to obtain a mean cross efficiency score for every supplier, and the supplier can be ranked regarding the scores [Talluri and Narasimham, 2004].

To solve the problems of the CCR model some formulations can be used to generate a unique set of weights:

$$\text{Minimize: } \sum_y \left(v_{ky} \sum_{s \neq 0} o_{sy} \right),$$

Subject to:

$$\sum_x \left(u_{kx} \sum_{s \neq k} I_{sx} \right) = 1,$$

$$\sum_y O_{ky} V_{ky} - E_{kk}^* \sum_x I_{kx} u_{kx} = 0,$$

$$E_{ks} \leq 1 \forall \text{ Supplier } s \neq k$$

$$u_{kx}, v_{ky} \geq 0$$

The objective of this mathematical approach is to obtain the maximum efficiency score for the supplier k and as well to establish a set of weights that minimize the aggregate output of the others suppliers. In this case the units emphasize in its strengths which are the weaknesses of their competitors.

3.4.6.1 Strengths and limitations.

The DEA approach is a useful procedure to make a first classification between suppliers classifying them as efficient or not efficient reducing the number of initial candidates helping to make the final decision, and reducing the possibilities of choose a bad supplier.

The main advantage of this method is that the decision maker does not need to predefine the weights which makes easy the practical implementation, but this also causes that the decision maker can not have any involvement or control for the importance of the criteria, and this is a limitation in many cases where the decision makers are able to state the criteria importance, although they can not the exactly value of the weights [Talluri and Narasimham, 2004].

3.4.7. Mathematical programming models.

The mathematical programming is “that branch of mathematics dealing with techniques for maximizing or minimizing an objective function subject to linear, nonlinear and integer constraints on the variables” [Dantzing et al 2003]. Mathematical programming allows the decision maker to formulate the problem as a mathematical objective function that needs to be maximized or minimized by varying the values of variable in the objective function.

In mathematical programming models the most frequently used techniques and also in their application to the evaluation and selection of suppliers process are the linear programming, mixed integer programming and goal programming.

The mathematical programming models can be divided in two main groups:

1. Single objective techniques.
2. Multiple objective techniques.

In the single objective group are included the linear programming models and the mixed integer programming, in the multi-objective group are located the goal programming models.

Multiple objectives can be adopted when none of the suppliers is able to satisfy the buyer’s total needs or when procurement strategies aim at avoiding dependency on a single supplier this would be a multisourcing approach, but it is also applicable to the evaluation of one supplier under the consideration of multiple objectives, which also is the most common application. In the multisourcing context the buyer faces two decisions: selecting suppliers and assigning orders among selected suppliers.

In the single objectives approaches is considered a single criterion (price minimisation typically) with constraints related to other criteria.

First I will make an explanation of the mathematical basis of the three most common methods: the linear programming, the mixed integer programming and the goal programming.

3.4.7.1 Linear programming

“The linear programming is concerned with the maximization or minimization of a linear objective function in many variables subject to linear equality and inequality constraints” [Dantzing, 2003]. Linear programming models determine the way to achieve the best outcome given some list of requirements represented as a linear equation.

Linear programming problems can be represented in a canonical form:

Maximize: $c^T x$

Subject to: $Ax \leq b$

Where: $x \geq 0$

X represents the vector of variables, while c and b are vectors of coefficients and A is a matrix of coefficients. The expression to be maximized or minimized is named the objective function $c^T x$. $Ax \leq b$ are the constraints over the objective function must be optimized. The constraints can be the buyer’s demand, supplier capacity, quality, etc...

This is a single objective technique where one criterion normally the cost is considered as the objective function and the other criteria are taken into account as constraints.

3.4.7.2 Mixed integer programming.

A mixed integer program is the minimization or maximization of a linear function subject to linear constraints just like as in the linear programming but some of the unknown variables are required to be integers.

There are two main problems with these single objective techniques: the criteria which are used as constraints are weighted equally, what is unlikely to happen in practise and the other main problem these models present is the difficulty to consider qualitative factors.

Some articles in the literature trying to deal with these problems. As for example by using the AHP model [Ghodsypour and O' Brian, 1998] to make the trade off between tangible and intangible factors and calculate a rating of suppliers, and then by applying these ratings as coefficients of an objective function in linear programming.

3.4.7.3 Multiobjective mathematical programming. Goal programming

Multiobjective mathematical programming is an extension of the traditional mathematical programming theory in the case of multiple objective functions need to be optimized [Doupous and Zopounidis, 2004]. The general formulation of a multiobjective mathematical programming is:

$$\text{Max / min} \{ f_1(x), f_2(x), \dots, f_n(x) \}$$

subject to : $x \in B$

Where:

X is the vector of decision variables.

f_1, f_2, f_n, \dots are the objective functions (linear or not lineal) to be optimized.

B is the set of feasible solutions.

In the multiobjective mathematical programming the concept of optimal solution is not applicable anymore; it is not possible to find a solution which optimizes at the same time the different objective functions. Then the main point is to search for an appropriate solution.

Goal programming:

The goal programming approach is an alternative to solve multiobjective problems. The idea of goal is different to objective. An objective defines a search direction as for example profit maximization. A goal defines an objective against which the accomplished solutions are compared [Doumpos and Zopounidis, 2004]. Goal programming optimizes the variations from the pre-defined objectives, rather than performance of the solutions. The goal programming approach is represented by Doumpos and Zopounidis as follows:

$$\text{Max/Min } g(d_i^+, d_i^-)$$

subject to:

$$f_i(x) + d_i^+ - d_i^- = c_i$$

$$x \in B$$

$$d_i^+, d_i^- \geq 0$$

where:

f_i is the i goal defined as a function of the decision variable x .

c_i is the target value for goal f_i .

d_i^+, d_i^- are the deviations from the target value representing the under-achievement and over-achievement of the goal respectively.

In this goal programming approach an objective function from multiobjective mathematical programming is transformed into a constraint. This method requires that the decision maker establish the priority order of the goals. If the solution is unacceptable, the priority structure can be reorganized but the number of possible reordering probably would be too high, a problem with five selection criteria has up to 120 priority reordering [Karpak et al. 1999]. The priority structure is an important matter here which has to be established with rigour for the decision maker.

Another limitation of goal programming is that lower priority goals may not affect the solution because the analysis stops as soon as the procedure finds an optimal solution [Karpak, 1999].

The articles I have found related to the supplier selection using mathematical programming as supporting tool are based on the approaches explained above but each author develop different mathematical models sometimes difficult to understand without a wide knowledge of the particular situation. This is also a limitation for the use of mathematical programming techniques because it is difficult to involve several persons in the decision making process. I will make here a review of the different approaches treated in the articles and the problems which they try to deal with.

One of the first authors to apply mathematical programming to supplier selection was Gaballa [1974]. He proposed a purchasing problem of the Australian post office, buying multiple items from suppliers who offered an all units quantity discounts. The objective was to minimize the total discounted price. He formulated a single objective to minimize the sum of purchasing transportation and inventory costs by considering multiple items, multiple time periods subject to vendor production capacity constraints and the buyer demand constraint. The problem was formulated as a mixed binary integer linear program and solving using a mathematical program system.

[Bender et al.1985] describes an IBM purchasing problem which involves multiple vendors, multiple products, multiple time periods, and quantity discounts. The objective is to minimize the sum of purchasing transportation, and inventory costs over the determined horizon, without exceeding vendor production capacities. A mixed integer programming is used to solve the problem.

[Sharma et al 1989] formulated a goal programming model to determine quantity, quality, and lead time requirements. Each of this requirements corresponded to a goal.

Weber and Current [1993] used a multiobjective approach to analyze the trade-off between the conflictive criteria in the supplier selection.

In the multiobjective models the objectives are in conflict. That is no one solution exists which is optimal for all the objectives. Therefore the multiobjective models are used to generate various non inferior solutions to the problem rather to identify a single optimal solution.

Multiobjective analysis has several advantages over single objective analysis:

Allows the various criteria to be evaluated in their natural units of measurement and therefore eliminates the necessity of transform them to a common unit of measurement, frequently a monetary unit, as a result these model present a set of non-dominated solutions.

The fact that the multiobjective model doesn't provide an optimal solution to the decision maker can be seen as an advantage by providing a set of noninferior alternatives and the trade off associated with them multiobjective approach allow the decision maker to apply its experience or insights before make the final decision.

Another major advantage of multiobjective techniques is that they provide a methodology to analyze the impacts of strategic policy decisions

3.4.7.4 Strengths and limitations.

As a resume of the main strengths and limitation of the mathematical programming models, I can say that the main advantage of the mathematical programming model is that the mathematical function gives them a more objective conception with a facility to optimize the objective established, it makes this approach look more effective that the linear weighting models, but also on the other hand, it can be argued that they just focus on the quantitative criteria, having problems to include qualitative factors which are very important in the decision making.

Their main strengths are that they are based on an objective evaluation, an objective procedure is used to obtain the results, and also some methods can provide an optimum solution. Some of the limits I have explained above make reference to the difficulty of involve different persons who can provide different points of view to the process because of the difficult interpretation of the models, there is also the problem of determines coefficients of the equations and the limits of the constraints, which requires a subjective statement that is not very clear the way in what is determined.

3.4.8 Artificial intelligence models.

The artificial intelligence techniques are based on computer-aid systems educated by a purchasing expert or by using historic data [De Boer et al. 2001]. The implementation of an artificial intelligence based system involves extracting from the experts the knowledge and methods used to solve a problem and reforming this methods and knowledge into an organized form to later use [Vokurka et al, 1996]. In this way, artificial intelligence models can be used as a tool to help decision makers who have to deal with similar but new decision situations. This is quite recent approach, but there are some examples of methods based on artificial intelligence technology that have been applied to supplier choice include neural networks and expert systems. A decision support system based on Neural Networks is presented [Albino and Garavelli, 1998]; Vokurka et al. [1996] develop an expert system able to support also the supplier selection phase. Another artificial intelligence based technology are founded in the literature as the CBR system [Cook,1997], this is a software driven database which provides a decision-maker with useful information and experiences from similar, previous decision situations. Khoo et al. [1998] introduce an internet based technology called intelligent software agents (ISAs) which they suggest as a tool for automating the procurement of goods [De Boer et al. 2001].

Though only few examples of AI methods applied to the supplier evaluation problem can be found in the literature it is important to mention these methods because of their future potentialities regarding to the intelligence information development.

The implementation of a system based on artificial intelligence to evaluate different suppliers requires normally the definition of some parameters as for example the problem environment, the parameters involved in the decision process, their measure and the desire type of rating [Albino and Garavelli, 1998]. With all these data introduced into the system, it will be able to provide the best solution, based in the previous experiences the system has learnt.

3.4.8.1 Strengths and limitations

One of the strengths of these models is a formalisation of the decision-making process is not necessary. [De Boer et al, 2001]. And thanks to that following the De Boer opinion model as the Neural Networks based models can deal under situations of complexity and uncertainty better than other traditional methods. The decision maker here just needs to introduce to the Neural Network model data which define the actual situation of the problem, as it could be the performance of the supplier on the different criteria. The Neural Network based on previous experiences or situations makes the decision for the user. But on the other hand, this strength can be seen as a limitation because it also means that the user of the model will not be able to explain to others how the final selection has been reached. This can be required in some situations as in the case of to suppliers that have not been chosen. This makes Neural Networks primarily suitable for situations where external justification is less important. [De Boer et al. 2001].

The main advantages of these types of methods are that the data base can be used permanently, can be used from different locations and is easy to document and also allow the transferability among different groups within the organization.

The complexity of the systems employed may not be suitable for every company to adopt these types of techniques without high capability in advanced computer programmers. For the majority of the small ad medium organizations the implementation of these models can represent an unaffordable expenditure [Choy et al. 2002]. Another problem concerning to this methods is the information available. The lack of historical performance records of suppliers can exclude the use of these approaches; in new tasks it is difficult to find historic information available.

3.4.9 Statistical models.

The models based on statistical tools used to supplier selection/evaluation are used to work with the stochastic uncertainty in the supplier selection process [De Boer et al. 2001]. The stochastic uncertainty is present in different purchasing situations, as for example the evolution of the demand of particular products. Another example of

uncertainty can be the lead time, an article by Ronen and Trietsch [1988] develop a decision support system for supplier choice and ordering policy in the context of a large project where the lead time is uncertain [De Boer et al. 2001].

Within the statistical models the Cluster analysis is a method which uses an algorithm to cluster several products categorized by a set of numerical punctuations into a number of groups in a way that the differences between items within a cluster are minimal and the differences between items from different clusters are maximal [De Boer et al. 2001]. Cluster analysis can just be applied to a group of suppliers that are described by scores on some criteria. The result is a classification of suppliers in clusters of comparable suppliers [Holt, 1998].

The multiple regression is another statistical technique introduced by Holt [1998], where an equation is constructed to observe and predict the effect of several variables upon a dependent variable. That is a multiple regression equation will predict a numeric outcome, this being a function of several independent variables. For a given scenario, represented by several dimensions, there will be an actual outcome. It is from the statistical analysis of several of these scenarios from which a multiple regression equation can be formulated.

Some authors have employed fuzzy set theory to handle factors involved in the supplier selection/evaluation as uncertainty, imprecise information or the change of importance of different criteria. [Amid et al, 2006]. Fuzzy set Theory provides the mathematical tools to modelling unclear preferences that make reference to not very accurate judgements as for example in the case of setting weights of performance punctuation on criteria [De Boer et al, 2001]. The Fuzzy set theory applied to supplier selection is explained in a broader way by Holt [1998]. He states that this theory can deal with multicriteria information which includes subjectivity and imprecision which are common characteristics to the supplier vendor selection problem. Morlacchi [Amid et al, 2006] present an example of the Fuzzy set Theory combined with AHP.

3.4.9.1 Strengths and limitations

The main advantage of these approaches is that an important factor as the uncertainty can be incorporated, but on the other hand, the statistical techniques are quite complicated techniques difficult to implement which involves complex computational features [Muralidharan et al. 2002]. I think these models have a more academic use, than a practical use in a real situation. But I also think that is good to mention them in this project because they are present in the literature and they are mentioned by several authors, and also because they introduce the factor of the uncertainty which is not wide covered by the other methods, but it is true that the number of articles I have found which treat them are not high and most of them use these techniques as a complement or combination for another of the most common models.

4. COMPARATION AND ANALYSIS OF THE METHODS.

4.1 METHODS COMPARATION.

Here I am going to compare the different methods explained above as a resume, pointing out their main advantages and limitations. A table is presented where these advantages and limitations can be observed.

Method	Advantages	Limitations
Total cost of ownership	Good quantitative approach. Objective. Good Source of data.	Difficult implementation. Many data are required.
Categorical	Easy to use. Easy implementation. Not much data are required.	Subjective. Shallow analysis of the situation.
The Weighted-point method	Easy to use. Easy implementation. Easy to understand	Subjective. Compensatory problem.
DEA	It does not require pre defined weight values. It can be used in the prequalification phase. Objective.	Lack of involvement or control for the importance of the criteria. Difficult implementation.
Outranking	Limitation of the compensatory effects. Cover situations of uncertainty. Structured process.	Difficult interpretation of the results. Subjective.

AHP	Point estimates for criteria weights are not required. Global view of the process. Structured analysis.	Results are dependent on the subjective judgements of the decision makers. Not straightforward.
Mathematical programming	Based on objective evaluation. Optimum solution.	Difficult implementation. Difficult to use. Difficult interpretation.
Artificial intelligence	Easy to use Deal with uncertainty Good Source of data.	Complexity of implementation. Difficult to gather the information.
Statistical	Deal with uncertainty.	Complexity of implementation

Some of the characteristics of each method which I present as advantages or limitations in the above figure have influence over other factors or characteristics; what I mean here it is that some of the characteristics of the models present a trade off between them as for example:

Complexity of implementation and advantages of use. The complexity of implementation term makes reference to characteristics as the amount of information and resources required to the method implementation or the complexity the method involves into the analysis of the problems, as for example if mathematical analysis are needed. The advantage of use includes factors as, easiness of use or the facilitation of a straight forward decision and the interpretation and the insight which the method provides. With this classification the suitability of the different methods can be evaluated regarding the complexity of the situation and the final result obtained from a cost benefit perspective.

The implementation of one method and also maintaining it can be very difficult, requiring a high economic effort or the use of other types of resources as high qualified personnel, but these efforts can be worthwhile if they are employed to create an easy model to use which can provide good results in following times as in the case of the artificial intelligence models, or a more structure and precise model which helps to better analyse the situation, so a balance between the complexity and costs required and the benefits provided by the different methods should be made depending of the situation.

Flexibility and structure. Flexibility can be difficult to obtain in a method which provides a structured view of the problem. A flexible method can limit the structuring function. Using a method which provides a structured decision process the understanding of the whole process is higher and insights of the purchasing situation can be gained. But these methods are at the same time difficult to implement or require more time and information. The term flexibility I use here makes reference to the adaptability of the method for possible changes in the purchasing situations. A method which provides a structured decision process normally is focused on a particular case or situation, and a change on the factors or criteria taken into account can make the process lose part of its utility, because its lack of flexibility a new process would need to be stated again, with the consequent expend of resources.

Objectivity and Subjectivity. The way in which information is introduced by the decision maker to the model is an important point. It may be hard to identify the most appropriate way to introduce the information. From one hand the acceptability of the outcome using personal judgements while the objectivity of the input information is important. The more objective techniques may present a lack of concern about the personal opinions or judgements of the decision makers, but this information can be really important, factors as personal experience or even the buyers feelings should be taken into consideration. But on the other hand the process should not be biased for these subjective criteria; an excessive dependency of the ideas or feelings of one person could involve in the decision external factors to the decision problem as special predilection for one particular supplier or friendship etc...

Quantitative and qualitative. The possibility to assess quantitative and qualitative criteria is an important question also in relationship with the use objective and subjective information. Quantitative criteria as price or delivery time can be easily introduced and evaluated using some methods, but when factors as commitment, trust or future development of the supplier need to be evaluated, it is hard to use the same models. The quantitative criteria are based on objective data which are easier to measure, under these characteristics a method based on objective procedures as the mathematical techniques do, which can provide an accurate evaluation would better employed. But on the other hand these methods can present problems for the inclusion

and evaluation of qualitative criteria, which are less measurable and where the use of personal opinions or previous experiences is crucial.

All the main methods explained are used for the final selection phase. Except DEA and artificial intelligence methods all methods try to rank the suppliers from the best to the worst or to choose the best supplier among others. DEA helps to classify the supplier as the efficient suppliers and inefficient suppliers; it is suitable for categorizing the suppliers into groups and investigates the differences between groups.

The artificial intelligence models work under the definition of the situation given by the decision maker and provide the best solution trying to match the actual situation with previous data included into the system.

Following the general characteristics explained above I have represented the next table where it is pretended to categorize the different methods regarding the mentioned characteristics. I have used an ascendant scale from 1 to 5, where a 1 means the worst performance and a 5 the best.

	TCO	Categoric al	Weighted point	DEA	Outrank.	AHP	Mat. Prog.	A. I	Stati stical
complexity	2	5	5	2	3	4	2	1	1
Advantages of use	2	5	5	1	3	4	1	5	1
Flexibility	1	5	5	2	3	4	2	3	2
Structure	2	1	1	2	4	5	2	1	1
Objective	3	1	1	5	2	2	5	3	5
Subjective	1	5	5	1	5	5	1	3	1
Quantitative	5	4	4	5	2	4	5	5	5
Qualitative	1	4	4	1	4	5	1	5	1

Regarding the term of complexity the artificial intelligence and the statistical models are the most complex, in the case of the artificial intelligence models as I have said before, it is required high qualified personnel and the use of many resources, besides the difficult to gather information to their implantation. The statistical methods involve complicated mathematical equations and procedures and also computational calculations to cope with the problem.

The mathematical approaches and DEA are also quite complex techniques since an important mathematical background is required to embrace these methods. But there are some particular models which allow the use of simpler equations if the problem is not too complicated. I have situated at the same level the total cost of ownership (TCO) method where the availability of data is very important to its implementation.

The Outranking and the AHP are techniques which allow the use of qualitative statements to assess the criteria making easy their use, they are not straight forward techniques a quite deep analysis of the situation is required, the Outranking method presents more complications as it can be the establishment of thresholds and also it doesn't present a so clear view of the process from an external point of view.

The categorical and the weighted point methods are clearly the easiest to use and to implement.

If the advantages of use of each method are analysed, after the categorical and the weighted point methods, the artificial intelligence techniques provides as easy and quick procedure held on the data base and the computerized system created.

The AHP is an easy method to used and understand, but requires an elaborated process which doesn't provide a straight forward answer; the same happens with the Outranking approach but here the interpretation of the results is harder.

The mathematical, DEA and statistical approaches are not friendly to use and to understand because of the mathematical considerations involves in them.

The TCO can be easy to use and direct to apply once it has been implemented by using a computerised system, but it would be required to work under a situation really similar to a former one. But under most common circumstances, the difficulty to gather the data and the analysis and estimation of the costs are the main characteristics contributing to its complexity of use.

Flexibility is an important characteristic included into the AHP model which allows the inclusion of possible changes during the process without cause important complications, the opposite to what happens to the mathematical models which are based on a particular situations and where changes are really difficult to implement. In models as the TCO the adaptability to changes is neither an easy matter, the estimation of costs is a difficult task which requires a deep analysis nor the changes would be easy to apply without a new estimation of the costs produced by the changes in the process. The flexibility is not the main limitation of weighted point and categorical methods.

The AHP and the Outranking models provide the most structured analysis of the situation, in these models many considerations are needed to take into account and factors as the establishment of preferences help to give these models a more structured view. This characteristic and the flexibility of the AHP model represent their strongest points.

The mathematical and statistical models can be qualified as objective models since they all use objective procedures as mathematical tools or analysis based on costs. Here quantitative criteria can be evaluated in an accurate way. On the other hand categorical, weighted point and Outranking and AHP are subjective models based more on personal judgements or opinions which fit better to evaluate qualitative criteria. But quantitative criteria can also be assessed with these models which use mathematical support to give the process more objectivity, but in spite of that I believe that this approaches have an important subjective influence.

The TCO model works as an objective tool when the costs are available from historical data when these have been already estimated from similar situations, but this is difficult to happen in each situation. The use of personal judgments is requires to the estimation of the costs when new situations or factor need to be taken into account.

The artificial intelligence models are quite special and difficult to categorise here because they use the data included in the system which are both quantitative and qualitative data and the model make a decision based on data introduced previously. This previously data are also based on personal feelings or experiences of decision makers and the decision system is based on a electronic program which is suppose to be out of the influence of the actual decision maker (except on the data introduced). So this approach is hard to classify either as subjective or objective.

4.2 FACTORS WHICH INFLUENCE THE SUITABILITY OF THE DIFFERENT SUPPLIER SELECTION METHODS:

Within this part of the project I am going to present some factors or situations of the purchasing process which can influence the suitability of the methods presented before.

4.2.1 Purchasing situations.

A diversity of situations can be differentiated into the purchasing field, situations which are defined by factors as complexity or importance. Here I define some of these purchasing situations which are mentioned by De Boer [2001]. Here three different kinds of purchasing situations are presented:

Straight rebuy or routine purchase. This makes reference to standardised products where the purchase is made automatically. The information about specifications and the suppliers is well known. The orders use to take place under existing contracts and agreements.

A modified rebuy. This buying situation can involve the following cases [De Boer et al 2001]:

1. A new product or service is purchased from known suppliers.
2. Known products are purchased from new suppliers.
3. The level of uncertainty is reasonable with respect to specifications.

A new buy. In a new buy the following situations can be faced [De Boer et al 2001]:

1. A new product or service is purchased without previous experience.
2. The suppliers are not known.
3. The level of uncertainty regarding the specifications is elevated.
4. The problem requires an extensive analysis.

This distinction between new buy, modified rebuy and straight rebuy can be a good point to classify the uncertainty into the supplier selection process. In the routine purchase the uncertainty doesn't exist while in the modify rebuy it is a factor to take into consideration and in a new buy is a crucial factor.

The main factor which defines the kind of purchasing situation is the type of product which is purchased or its characteristics; there are products with an extreme complexity, or strategic importance which lays a big part of the achievement of the objectives of the company. The supplier selection in this case is not analysed as in the case of routine products. In this case searching for a more exclusive relationship with the supplier aiming at the establishment of a partnership seems to be more appropriate, with an early supplier involvement, and the supplier selection becomes a crucial matter. The evaluation criteria goes beyond the price, quality and delivery factors, looking for a evaluation of more intangible criteria as commitment, trust, flexibility or adaptability, skills development.

A useful framework where the dimensions of complexity and importance in the purchasing situation are analysed is the Kraljic's matrix [Van Weele, 2005]. Here a classification of different products regarding to their influence to determine the purchasing situation can also be made.

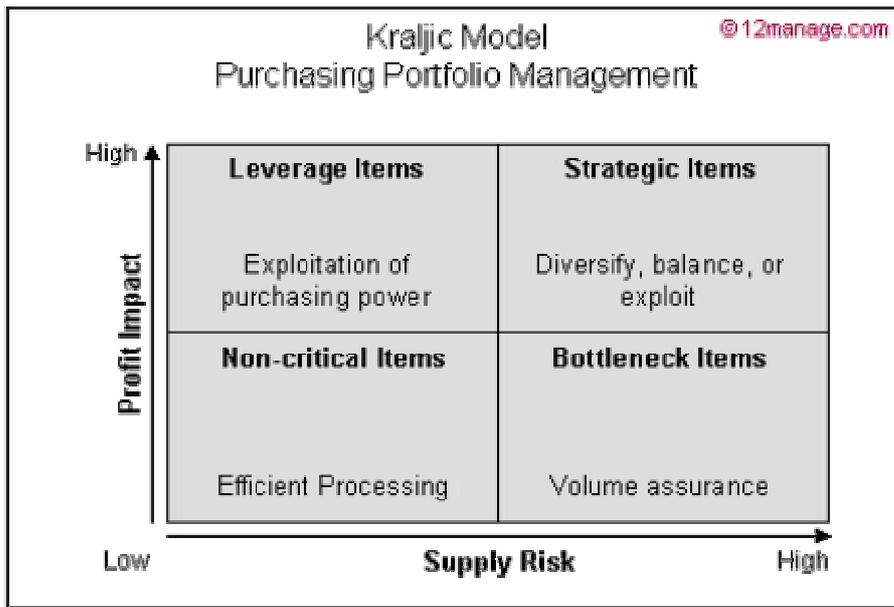


Figure 2. Kraljic Matrix [Google images, 2008]

In this matrix the purchasing situation is identified by two factors: profit impact and supply risk. The profit impact or financial risk includes the expenditure with the purchases and the impact on the future quality of the product or service. The supply risk includes the availability of the goods or services and the number of potential suppliers. According to the values obtained in these factors the products can be grouped as in the Kraljic’s matrix: Strategic products, Leverage products, Bottleneck products and routine products.

In the case of non-critical items or also called routine products, these have small value and produce limited problems, there are many suppliers that can provide them, but because of these reason, it will not be worth to spend a large amount of resources to select suppliers. Products frequently used and ordered are grouped in the routine purchase

The bottleneck products represent a limited value but produce a strong dependence on the suppliers, the supply risk is high for the scarcity of materials or a unique specification, and these products are characteristics of a monopolistic supply market.

The strategic items, these can be products very specific characteristics as high-tech, high volume products which are often supplied to customer specification, there are a few suppliers, a relationship of development and partnership with the suppliers is pursued. In these products the supply risk is high and its importance is crucial for the company.

Leverage products can involve modified rebuy situations. The number of supplier here is high and these products represent an important value for the company, factor that justifies an intensive evaluation and selection suppliers process.

4.2.2 Purchasing sector

The sector where the firms develop their activities and where purchase takes place can have an important influence in the process of supplier selection. An extensive review of different sectors and their particularities regarding the supplier evaluation/selection process and their influence in order to choose a method to support the process could be made here. But I am just going to make a differentiation between the public and private sectors. I find it interesting to include in this project a reference to the particularities of the public sector because of its importance and singularity with respect to the other sectors. The public sector is a really special scenario where different directives and issues must be taken into account. The establishment of a partnership with a unique supplier or a reduced group of them is not applicable here. The rules to protect competition and to avoid a privilege treatment don't allow the establishment of a long term relationship and favour a competitive bidding process.

In the public procurement there are some directives issued by the European Commission [Van Weele, 2005] with the aim of structure the tender procedures on the public sector. These directives mainly involve the following principles [Baily et al. 1998]:

1. Increase the transparency of procurement procedures and practises throughout the community.

2. Aid the free movement of goods, services, capital and people between member states.

3. Develop effective competition for public sector contracts.

4. Standardise specifications.

5. Provide advance information of procurement needs to the market place.

Under the operation of these directives as I have said the establishment of an exclusive and long term relationship is hardly implemented, because of the need to open a new process to chose the most suitable supplier after every new purchase, to guarantee a wide market an a high level of competition.

4.2.3 Different kind of products.

Here I am presenting a classification of the different type of products an organisation may need to acquire to perform its activities these include from raw materials to services.

Commodities:

The primary commodities are represented by natural products rather than by manufactured products. Some examples of the main commodities used in the industry are copper, aluminium, gas oil, silver, lead, coffee, grains ... A distinction can be made between natural raw materials and minerals [Van Weele, 2005].

There is a main problem when commodities are to be purchased, and this problem is the large fluctuations in price which often occurs in short periods of time. This price variability represents an important shortcoming to a purchaser who needs important amounts of commodities to support its production and even more when the products are sold at prices which can not varied in the same way as the commodities do. [Baily et al.1998]. These problems with the price fluctuation can also affect the secondary products which are influenced by the primary commodities. It is also important to say that the purchase of these products involves an important amount of money.

The fluctuation of the commodity prices can be caused by several factors, as for example political or economical changes, changes in technology or the availability of a substitute product, or the existence of a competitive market, and if the commodities are agricultural products, factors as the weather are crucial.

Other factors as the geographical location which influences the transportation of raw materials [Van Weele, 2005] have also great importance in the purchasing of raw materials.

Capital goods.

The purchase of capital goods is mainly for long term requirements, to be employed in the production of other goods or services, capital goods are considered to have a life longer than one year, some examples of capital goods can be buildings, plant and machinery or computers.

Because of the long life of these products some factor as product support, availability of spares, after sales service, stability of the supplier [Baily and Farmer, 1998] must be taken into consideration.

Other special factors are applicable here as it can be cash grants which can be available for the investment on some equipments or factories in some particular places. Taxes must also be taken into account in a purchase of capital goods; they can make an important difference to the expected return and also to the final decision of make the purchase or not.

Components.

Components are parts which are to be built into the final product, to be sold by the manufacturer [Van Weele, 2005]. A differentiation between standard and specific components is made by Van Weele. The standard components are those which are manufactured following the supplier specifications, and the specific components are those manufactured following the buyer specifications.

Components are usually purchased for serial production; they used to be negotiated in annual or long term agreements.

The main factor to take into account when purchasing components is the quality, a defect in one of the components can cause important damages in the production system. Usually a supplier is just included in the list of possible suppliers if it has passed an audit which certifies it is able to deliver the required product under a certain limits of quality.

Maintenance, repair and operating products (MRO).

The main characteristics of these products are the following [Van Weele, 2005]: There is a large variety of these types of products, but they don't represent a high economical value for the companies.

The MRO products can be comprised for articles of different level of specificity, some of them are standard (office materials) an in the other hand some of them are really specific as it can be in the case of spare parts for production.

The level of use of the MRO products is difficult to predict, and that makes that the inventory is maintained at a low level.

The selection of the product is very influenced by the final user.

Services.

Services are defined as any kind of supply where the main component is a task of some kind, rather than the provision of some tangible good or material [Baily et al.1998]. A service is a performance of some act of value which does not result in the customer ownership of anything.

The services present some characteristics which differences them from the tangibles products, some of these characteristics are the impossibility of storage, what means that they have to be provided when they are needed.

Other characteristic of the services is their difficult to be evaluated, services can not be evaluated until they are performed, it is difficult to make a pre-evaluation or something similar, but it is not either easy to evaluate the service once it has been provided,

because the evaluation of this can be quite subjective which can be reflected in contractual problems when reach an agreement about the requirements expected from the service provided can be hard to obtain.

Some kind of services as banking or insurance services has the advantage that they don't need to be provided in a particular physical place.

It needs to be said that it is difficult to find a purchase of goods which doesn't involves the supply of services and vice versa as well. But there are some type of services which can be considered just service or as for example the mentioned before, the insurance service and banking service but also consulting services or activities which are needed for the company every day working but they are not related with the core activity of the firms as it can be clothing or restaurant services...

4.2.4 Type of relationship.

One of the most important factors to manage buyer supplier relationships is by knowing the strengths and limitations of the suppliers. This requires a good evaluation of the potential suppliers. A good performance on the evaluation here must look into the past activities performed by the potential supplier and not just for the future ones, to detect possible problems. This is important if the type of relationship which is pretended to establish is a partnership where future projects want to be developed. The purchaser here must take into account more and relevant alternative criteria, also here is specially needed to deal with intangible factors as trust, besides the quantitative factors. And also a method which helps to structure the problem, which can help the buyer to find the real problem, to find what it is really needed from the suppliers.

4.2.5 Number of suppliers available.

The availability of feasible suppliers for a specific product or service can influence the selection of the evaluation methods. If the number of available suppliers which can meet the buyer requirements for a specific product is large, one of the methods which allow a sorting process would be suitable. On the other hand if the number of supplier is reduced, the main function of the method here is help to ranking those suppliers following the criteria established by the decisions makers.

These both factors, type of relationship and number of suppliers available are factors which also influence the purchasing situation and which are included in the analysis of it, these is the reason why in the next section of the project which is devoted to the analysis of the factors which influence the suitability of the different supplier selection methods I will not include a separate chapter to analyse them, instead I will discuss their impact within the chapter where I analyse the influence of the different purchasing situations.

4.3 ANALYSIS OF THE FACTORS WHICH INFLUENCE THE SUITABILITY OF THE DIFFERENT SUPPLIER SELECTION METHODS:

In this chapter I am going to analyse the factors I have presented in the past chapter explaining which characteristics would be more appropriate to a method used for supplier selection/ evaluation under the circumstances of these factors.

4.3.1 Purchasing situation.

Factors as the complexity and the importance of the purchasing situation can affect the suitability of the method to use to evaluate the possible suppliers. Here a

description of factors which in different purchasing situations can affect the suitability of the different methods is presented.

Straight rebuy or routine purchase. In this case the priority is to use a method where the information is easy to access, the method is easy to use, and because these types of purchases include items already used and known and the main help which can be obtained from the methods here is to enable a faster and automated analysis of the information. It is important with access to historical data of suppliers, the criteria used previously can be also used here. Here the set of possible suppliers is not too large, because the product has been purchased before and it is possible to have a small base of providers. The method should help ranking the suppliers rather than sorting them.

A modified rebuy. In this situation the level of uncertainty is higher than in a routine purchase, but the availability of historical data from past purchases is also important, the situation is not completely new, so an extensive analysis of the problem is probably not required, this would mean a higher expenditure on more resources which may not be necessary.

Here the set of initial suppliers can be larger, maybe a sorting of suppliers could be made before ranking them.

New buy. These are more complex situations where the level of uncertainty is higher. In this situation the historical data are not available, and previous criteria can not be used. Here the number of supplier can vary depending on the product.

The product characteristics are in deep relationship with the purchasing situation because, some of the factors which characterize the purchasing situation are the characteristics of the products involved in the purchase.

Routine products. In this case there are many suppliers that can supply the item, and because of the low value of the product it is not worth to invest much in the supplier selection. Since the products provided by different suppliers are similar, criteria as the price or time to delivery becomes the most important, what makes ideal the use of an objective technique which can use data of past purchases.

Bottleneck products. These are a really special type of products where probably the method to select suppliers does not have a real influence, because these products use to be provided for a unique source which use to has lock in the buyers, and the election is really difficult.

Strategic products. These products use to be very specific, and the number of suppliers who are able to provide them is limited. This characteristic acts as a limitation to the sorting methods, then the choice set use to be small. To evaluate suppliers who can provide products with unique specifications, an evaluation of both qualitative and quantitative data is required because of the specificity of the situation where not historical data are useful. Qualitative data as trust or commitment have an important relevance here, factors which are important if a long relationship is pretended to set up and because of the importance of these product it seems to be a good option. A method which is able to include these appreciations and to structure the situation would be appropriate. A structured analysis is really needed here because of the specificity and high value of the products.

Leverage products. In this case the products have an important value for the company but they use to be less specific products which can be provided by many different suppliers. In this case the use of a ranking method would be appropriate to work with a small set of suppliers which can live up the expectations, because between these set of suppliers the differences are not important and shift to another supplier would not be a big problem. Also here the importance of quantitative data seems to be more important than qualitative data.

In the following table I present a classification with the aim of point out the more appropriate characteristics and advantages a method to support the supplier selection/evaluation should provide under each of the different purchasing situations explained before. To do that I include in the table the main characteristics of each purchasing situation, that I resume in four main characteristics: standardisation, level of uncertainty, the value of the products, and the number of supplier available.

Purchasing Situation	Characteristics	Characteristics Method Required
Straight rebuy	High standardisation. Not uncertainty. Suppliers and products are known. Reduced number of suppliers.	Easy to use. Historical data availability. Easy information access. Straight forward method. Possibility to evaluate quantitative data
Modified rebuy/routine product	Moderate uncertainty. Low Value Products. Low standardisation Large number of suppliers.	Historical data availability Possibility to deal with a large number of suppliers. Straight forward method. Possibility to evaluate quantitative data. Not many resources required to implementation.
Modified rebuy/strategic product	High value products. Moderate uncertainty. High specificity. Moderate number of suppliers.	Historical data availability Structured Process. Possibility to deal with qualitative and quantitative data.
Modified rebuy/leverage product	High value products Low specificity. Easy to change supplier. Large number of suppliers.	Historical data. Possibility to evaluate quantitative data. Not many resources required to implementation. Possibility to deal with a large number of suppliers.
New buy/routine product	Low value products. High number of suppliers. Low specificity Moderate level of uncertainty.	Possibility to deal with a large number of suppliers. Possibility to evaluate quantitative data (Price, Delivery time)
New buy/strategic product	High level of uncertainty. High value products. High degree of specificity. Reduced number of suppliers	Small number of suppliers. Not historical data available. Possibility to deal with qualitative and quantitative data. Structured method.
New buy/leverage product	High value products. Low degree of specificity. Low level of uncertainty. Large number of suppliers	Quantitative data. Possibility to deal with a large number of suppliers. Structured Process.

Looking at these four characteristics of the different purchasing situations represented in the table an association with the characteristics which a suitable method to support the supplier selection should have can be made. Thus if the number of available suppliers under this situation is large the use of a method which allow us to deal with them could be a good help if it is pretended or required to have an evaluation of them. Regarding to level of specificity, in this term, concepts as the products standardisation or complexity is included, and this can influence the data to evaluate

with the selected method, for example a high level of specificity may require take into account qualitative data, instead a less specific purchase may need better evaluate quantitative criteria as price or delivery time.

The level of uncertainty also affects the data to be evaluated, thus a high level of uncertainty requires the assessment of qualitative criteria as trust or commitment, and also the possibility to use historical data from past buys is related here, because when the availability of historical data is possible makes the decision less uncertain.

The high value of the products stresses the need for a structured method, rather than an easy to use and cheap to implement method. When the investment is important, the consideration of multiple factors is required, these factors can make reference to quantitative criteria, but also qualitative data, since the opinion of different people from different departments of the organisation who can be involved in the purchased may be required. It is also true that the used of a structured model can be linked to the novelty or specificity of the product as well as its value, because when the value of the product is high but it is also well known, other methods which allow the use of past data or the evaluation or quantitative data can be also suitable.

After I have indicated which characteristics would be the most helpful under each different situation, a classification of the different methods can be made to each of these situations. I am going to categorize the methods under the criteria of suitable, not suitable or possible. The term possible means that even I don't think that the method be the most appropriate under those particular situations, it could be a possible option either because the suitability of some characteristics of the method or because the disadvantages of use it are not too high.

Situations	TCO	Weighted point	DEA	Outrank.	AHP	Mat. Prog.	AI	Statistical
Straight rebuy	Suitable	Suitable	Not suitable	Not suitable	Not suitable	Not suitable	Suitable	Not suitable
Modified rebuy/routine product	Suitable	Suitable	Not suitable	Not suitable	Not suitable	Possible	Suitable	Not suitable
Modified rebuy/strategic product	Not suitable	Not suitable	Possible	Suitable	Suitable	Not suitable	Not suitable	Not suitable
Modified rebuy/leverage product	Possible	Possible	Suitable	Not suitable	Not suitable	Suitable	Possible	Not suitable
New buy/routine product	Not suitable	Suitable	Possible	Not suitable	Not suitable	Possible	Possible	Not suitable
New buy/strategic product	Not suitable	Not suitable	Not suitable	Suitable	Suitable	Not suitable	Not suitable	Not suitable
New buy/leverage product	Not suitable	Suitable	Suitable	Possible	Possible	Possible	Not suitable	Not suitable

Straight rebuy, Modified rebuy/routine product. Under these situations the availability of data is really important. Here the amount of data available from past similar situations should be high. With an important amount of data both methods the TCO and artificial intelligence could be used, the models based on the artificial intelligence also provide an easy and fast use and allow the use of tools as the internet which can also make transactions more direct avoiding administrative costs. But the main problem of these techniques is the elevated amount of resources required to implement them when the value of the products here is low. The weighted point models which are easier to implement could be appropriate.

Modified rebuy/strategic product. In this situation the strategic character of the products makes better use a model which can provide a structured analysis of the problem and some support with the uncertainty which the outranking approach can provide. The modify rebuy makes important past experiences and personal opinions based on them, so the introduction of qualitative criteria can be worth. The AHP and the outranking are the models which better cope with these characteristics.

Modified rebuy/leverage product. In this case is important to deal with an elevate number of suppliers and the measurement of objective data as price time to delivery, etc, the both methods are good dealing with objective evaluation and the DEA method can also provide a previous classification of efficient suppliers if the number of candidates is high. If the number of suppliers is reduced mathematical models can help to evaluate the objective data mentioned before.

New buy/routine product. Here is not possible to use past data, and the characteristics of the product aim at not using too many resources, where the evaluation should be made of quantitative data as price or delivery time. Weighted point methods could be fit here, and may the use of a simple mathematical approach.

New buy/strategic product.. Under this situation which is probably the most difficult I would chose use the AHP model which provide a consistent and structured analysis of the particular problem, but also the Outranking approach provided a consistent analysis an some problems regarding to the uncertainty can be treated here.

New buy/leverage product. Here the outranking can be useful for the uncertainty level which every new purchase carry and the DEA because of its characteristics to deal with an elevate number of supplier and with objective or quantitative data.

Both the categorical and the statistical methods are methods which I don't consider suitable under any purchasing situation, the first because of its simplicity and the statistical techniques both for their difficulties to implement and understand, which make them more appropriate for academic fields rather than for real case applications.

4.3.2 Type of products.

Commodities. The raw materials I have said before that the main problem here is to deal with the price uncertainty, which is an important problem for the explained methods, except for the statistical models and under certain conditions the outranking approach.

Some buying techniques are presented [Baily et al 1998] to deal with this price uncertainty.

MRO products. These kinds of products can be associated with the routine products and the routine buy.

This type of products cause important load of administrative work because of their diversity, their irregular consumption and their large number. The supplier selection for these products should be aimed at an efficiency increase of the purchasing process. Some possible measurements to use would be the standardization of the products, working with a specialized supplier, and important factors to select the supplier would be in this case as ordering directly from the user without intervention of the purchasing department, the electronic ordering possibility and working with electronic catalogues are decisive factors to select a good supplier.

Components. In the components the quality is the most important factor to consider and because of that the suppliers are just included into a list of feasible suppliers if they after been audited with respect to their quality system and production process [Van Weele, 2005] are able to provide the product under the quality requirements established by the buyer. After this audit the list of feasible suppliers should be reduced. As I have said before a distinction between standard and specific components can be made here. The standardised components allows an easier selection, because all the technical characteristics don't need to be evaluated, and just criteria as the price or delivery time or reliability in the deliveries need to be evaluated and also this products can be provided easily by the rest of supplier included in the list, so the

change of supplier doesn't mean a real problem here. When the components are specific the supplier selection becomes more difficult and other factors acquire more importance to the selection of the right supplier. When a specific product is required the technical capabilities of the suppliers must to be evaluated and also financial situation and future development, a more fluent flow of information between the two parts is as well needed, and as I have already said in the part of the project regarding to the buyer supplier relationships, this can involve a mutual trust to reach an optimum solution. These requirements make clear that once a supplier for a specific product is selected, it is difficult to change to another supplier and this would mean an important use of resources. In this situation a method which helps to include in the evaluation such a criteria as mutual trust or commitment would be appropriate.

Capital goods. The purchase of the capital goods requires a method suitable for group decisions because of the implication of different departments of the organization in the buy and also because of the importance of the products which used to require an important investment. A method which provides a good structure of the situation and which allows the measurement of all the technical qualities and capabilities involved, as production capacity grade of technology employed on the process, and also the financial situation or previous experience. But also subjective criteria as the trust are important here, since once the supplier has been chosen the possibilities to shift are small.

Services. Here I will just make reference to the services which can be clearly differentiate as services when the supply is an intangible task as in the definition given before was indicated, excluding here the analysis of the situations where the distinction between services and tangibles goods are not that clear.

Some of the differences which must be taken into account when buying services if a comparison is made with the purchase of goods is that some additional factors have to be take into consideration as taxes payment, social security or insurance.

The main factors regarding the suitability of the methods here is the difficulty to obtain exact evaluations of the services. They are difficult to measure in an objective manner, and the procedure to evaluate the feasible suppliers seems to be more adequate to those methods which allow a better inclusion of qualitative data and or qualitative statement.

The main characteristics of each type of product are presented in the following table and these are also related to the characteristics which a method to provide a good support should gather.

Type of product	Characteristics	Characteristics Method Required
Commodities	High value Low specificity High level of uncertainty.	Deal with uncertainty. Possibility to evaluate qualitative and quantitative data. Structured.
MRO Products	Low value Low specificity Low level of uncertainty.	Possibility to evaluate quantitative data. Historical data availability Easy to use Easy access to data. Straight forward method
Components/specific	Reduced number of suppliers High value High level of uncertainty. Reduced number of suppliers.	Possibility to evaluate qualitative and quantitative data Structured. Small number of suppliers
Components/standardised	Reduced number of suppliers High value. Low level of uncertainty. Large number of suppliers.	Possibility to evaluate quantitative data. Historical data availability Possibility to deal with a large number of suppliers.
Capital Goods	High value. Reduced number of suppliers.	Structured. Qualitative and quantitative data.
Services	Difficult to evaluate. Impossibility to storage.	Possibility to evaluate qualitative data Easy evaluation or assess of criteria

The characteristics of the different products described are very similar to the characteristics which define the different purchasing situations presented earlier, but products as the commodities present really particular characteristics as I have already said. The raw materials represent a high value for the companies and their main issue is the price variability which as I have explained is influence by many external factors. In this situation probably the personal experience or a good environmental analysis, and with the term environmental I mean the factors with a possible influence in the fluctuation of the price, are probably the most important factors to choose the right supplier. This kind of analysis I think is quite difficult to provide by the methods explained in this project, although it is true that an approach as the AHP which allows the inclusion o personal judgements and requires a structured analysis could help.

The services also present particularities which mainly make reference to the way they are assess, they are difficult to evaluate in a objective way, so the introduction of subjective judgements are important to their evaluation.

A categorization of the different methods regarding the type of product purchased is presented in the next table. To categorize the methods I have use again the terms of suitable, possible and not suitable.

The categorical method is not includes in the table for the same reasons I have stated before.

Type of product	TCO	Weighted point	DEA	Outrank.	AHP	Mat. Prog	A.I	Statistical
MRO Products	Possible	Suitable	Not suitable	Not suitable	Not suitable	Suitable	Suitable	Not suitable
Compon ents/spec ific	Not suitable	Not suitable	Possible	Suitable	Suitable	Not suitable	Not suitable	Not suitable
Compon ents/stan dardised	Not suitable	Possible	Possible	Not suitable	Not suitable	Possible	Possible	Not suitable
Capital Goods	Not suitable	Not suitable	Possible	Suitable	Suitable	Not suitable	Not suitable	Not suitable
Services	Not suitable	Suitable	Not suitable	Possible	Suitable	Not suitable	Not suitable	Not suitable

With respect to the MRO Products, to the purchase of this type of products the artificial intelligence based models and TCO provide an important amount of data based on previous operations, and the artificial intelligence models could make easier and faster the purchaser process.

Components/specific, here I consider the AHP as the most suitable model because of importance of these products and the possibility to make a structured analysis of the specific situation.

Components/standardised, to the selection of suppliers for these products methods which support the objective evaluation of quantitative criteria would be appropriate the mathematical programming approaches and the DEA model can be employed under these conditions.

Capital Goods for these products where the investment required is important a complete analysis provided by the AHP or the Outranking model seems appropriate.

Services, for the evaluation of possible suppliers of services the inclusion of subjective considerations and the easy way to assess the candidates which the AHP model allows make it as the most helpful model.

4.3.3 Purchasing sector.

In the public sector the procurement directives represent a limitation about the criteria to use to select or reject a bid from a potential supplier. These directives offer two choices upon which to base the selection [Baily et al. 1998]:

The first one is considering just the lowest price, where the only consideration affecting here is the price without considering any other factor. Under this situation and with just one criterion taken the attention the use of a method to support the selection is not necessary.

The other option is to choose the offer which present most economical advantages, where factors as quality, durability, delivery or after-sales service are taken into account when the cost is analysed with the objective to choose the offer which better meet the needs. The Total cost of ownership is a tool that allows the analysis of the costs incurred through the purchasing process and evaluate the possible suppliers in order to them, that makes this model an appropriate tool to uses in this situation. A method as the DEA approach could be useful, where the different suppliers are qualified as efficient or not efficient by following an analysis of the service or product obtained and the resources needed to obtained.

Other models could be applied here, the mathematical approaches could be useful since the evaluation of qualitative criteria as durability, delivery or price is important.

The AHP or the outranking approach doesn't seem to be the most appropriate approaches to use here, since the measure of costs to asses the criteria is not their main

advantage and the preferences stated over the different criteria are more based on personal judgements.

5. CONCLUSIONS.

As the importance of the supplier selection has increased over the last years, the presence of different models and techniques to support this decision has also increased. The increased of concern about supplier selection has been reflected in the literature research with an important presence of articles about the topic. The supplier's selection is a key factor in the company's strategy, and such a decision can not be made without an analysis of the situation which helps to make sure the right supplier is chosen. Here is where the methods for supplier selection/evaluation try to find their utility.

The use of models to support the supplier selection decision is needed to help to better understand and analyse what the real problem is. From a general perspective these models can help to improve the decision process by making the decision maker take different criteria into account, help to model and define the situation in a more precise way or force to the decision maker to study more in detail the influential factors. The use of these methods can also help the decision makers to improve their skills, enabling a better management of the information, as saving data for a future use and structure selection situations, facilitating communication.

It is clear that the supplier selection is not an easy task and that the different methods presented in this project can be a good help. But the described approaches are not an infallible tool which can be used in every situation and which guarantee an optimal solution. As it has been presented in this project, there are a wide variety of available techniques and models to support the selection/evaluation of supplier, these techniques present a varying complexity and possibly solutions. Some methods seem to be more adequate for a particular situation or present an affinity to deal with some particular factors involved in the purchasing process. The benefits of using these methods are conditioned by their correct application, and with correct application I mean the application of the method which best fit in every particular situation. The efficiency of the models is determined by a whole knowledge and understanding of the different methods and the context or situation where they can be applied. The advantages and the limitations must be appreciated, and these have to be studied under the particular characteristics of the problem faced.

Within this project I have explained how the suitability of the different approaches is influenced by different situations and factors. Some of the models explained can be really useful for some particular situation, but on the other hand can represent more a problem than a help under other circumstances.

I have distinguished and analysed between different factors which can modify the suitability and also the efficiency the methods can provide. I have analysed different purchasing situations and different type of products, other factors as the purchasing sector have also been mentioned.

After the study of these different situations is clear their influence over the evaluation/selection methods, and how the suitability of the different methods depends on the situation they are used.

Each method presents a number of particular characteristics, which in one or another way can be linked to a specific situation and their particular characteristics the decision maker faces.

As a final conclusion this project has tried to present and describe some of the method most employed in the process of supplier selection. The different methods have been categorised regarding the context the selection takes place. This categorisation was based on the understanding I have gathered from the articles I have read and where the description of the methods as been based upon. This study can be called more as a further description of the methods based on the opinions I have gathered after the presentation of the methods than a categorisation. Since any practical verification of the results presented has been carried out.

Since this study is based on a literature review, making a categorisation of the different supplier selection models is not an easy task, first because in the literature is common to find a biased position by many of the authors which use to make an extreme defence of their models in their articles, where they use to defend the applicability of their models in an excessive number of situations. Second is not easy to find cases on the literature about real cases where the models have been applied to.

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Figure1. http://www.learnmarketing.net/porter_1.gif. 29/06/2008.

Figure2.<http://wiki.mbalib.com/w/index.php?title=%E5%8D%A1%E6%8B%89%E6%9D%B0%E5%85%8B%E6%A8%A1%E5%9E%8B&variant=zh-tw>. 29/06/2008

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INFORMATION RESEARCH APPENDIX

Business Source Premier:

Search phrase	Article (tot)	Articles (potentially relevant)	Articles(chosen)
Suppliers selection and supply chain	195	13	<p>Ng, Wan Lung. European Journal of Operational Research, May2008</p> <p>-By: Yee-Ming Chen; Pei-Ni Huang. Benchmarking: An International Journal, Sep2007</p> <p>Supply Chain Management, Jun2007</p> <p>Chan, F. T. S.; Chan, H. K.; Ip, R. W. L.; Lau, H. C. W(2007)</p> <p>By: Araz, Ceyhun; Ozkarahan, Irem. International Journal of Production Economics, Apr2007</p> <p>Yigin, I. H.; Taşkin, H.; Cedımoğlu, I. H.; Topal, B. Production Planning & Control, Jan2007</p> <p>Bayrak, M. Y.; Çelebi, N.; Taşkin, H. Production Planning & Control, Jan2007</p> <p>Amid, A.; Ghodsypour, S.H.; O'Brien, C. International Journal of Production Economics, Dec2006</p> <p>Chen, Sheu Hua; Lee, Hong Tau. International Transactions in Operational Research, Nov2006</p> <p>Benchmarking: An International Journal, Sep2006</p> <p>Chen, Chen-Tung; Lin, Ching-Torng; Huang, Sue-Fn. International Journal of Production Economics, Aug2006</p> <p>Chan, F. T. S.. International Journal of Production Research, 10/15/2003</p>

Suppliers selection and supply chain and supplier evaluation	9	2	Araz, Ceyhun; Ozkarahan, Irem. International Journal of Production Economics, Apr2007 Chen, Chen-Tung; Lin, Ching-Torng; Huang, Sue-Fn. International Journal of Production Economics, Aug2006
Suppliers selection And AHP	25	3	By: Nydick, Robert L.; Hill, Ronald Paul. International Journal of Purchasing & Materials Management, Spring92, Vol. 28 Issue 2, p31-38 By: Narasimhan, Ram. Journal of Purchasing & Materials Management, Winter83, Vol. 19 Issue 4, p27-32 Benchmarking: An International Journal, Sep2006, Vol. 13 Issue 5, p566-579, 14p; (AN 22970681)
Supplier selection and artificial intelligence	9	2	K.L.Choy, W.B.Lee, V.Lo. (2003). K.L.Choy, W.B.Lee, V.Lo. (2002).
Supplier selection And total cost of ownership	13	2	Ramakrishnan Ramanathan (2007) Degraeve, Zeger, Roodhooft, Filip (1999)
Supplier selection And topsis	2	1	C.H. Cheng, J.W. Wang, K.C. Huang. (2007)
Supplier selection And mathematical programming	13	0	

International Journal of Production Economics

Search phrase	Article (tot)	Articles (potentially relevant)	Articles(chosen)
Supplier selection methods	25	1	Fuh-Hwa Franklin Liu and Hui Lin Hai. 18 September 2005
Vendor selection and purchasing decision making	3	0	
Supplier	37	0	

selection and Purchasing			
Supplier selection and purchasing decision making	14	1	Luitzen de Boer, Leo van der Wegen and Jan Telgen, June 1998

European Journal of Purchasing and Supply Management

Search phrase	Article (tot)	Articles (potentially relevant)	Articles(chosen)
Suppliers selection and supply chain	42	6	Shuo-Yan Chou and Yao-Hui Chang, May 2008 Sung Ho Ha and Ramayya Krishnan, February 2008 A. Amid, S.H. Ghodsypour and C. O'Brien December 2006 Chen-Tung Chen, Ching-Torng Lin and Sue-Fn Huang, August 2006 Fuh-Hwa Franklin Liu and Hui Lin Hai, September 2005 Rohit Verma and Madeleine E. Pullman, December 1998
Supplier selection and methods	38	3	Riccardo Dulmin and Valeria Mininno, July 2003 Luitzen de Boer, Eva Labro and Pierangela Morlacchi, June 2001 Luitzen de Boer, Leo van der Wegen and Jan Telgen, June 1998
Supplier selection methods and mathematical programing	11	3	Ali Kokangul and Zeynep Susuz, February 2008 Ezgi Aktar Demirtas and Ozden Ustun, 21 December 2006

			S. H. Ghodsypour and C. O'Brien, 20 September 1998
Supplier selection methods and artificial intelligence	1	1	K. L. Choy, W. B. Lee and V. Lo, February 2003
Supplier selection methods and outranking	2	2	Riccardo Dulmin and Valeria Mininno, July 2003 Luitzen de Boer, Leo van der Wegen and Jan Telgen, June 1998
Supplier selection methods and total cost ownership	2	1	Zeger Degraeve and Filip Roodhooft, January 1999

European Journal of Operational Research:

topsis	10		<i>European Journal of Operational Research, Volume 186, Issue 2, 16 April 2008, Pages 720-734</i> Hsu-Shih Shih
Topsis and purchasing	1	0	
Supplier selection And total cost of ownership	2	0	
Purchasing and data envelopment analysis	3		<i>European Journal of Operational Research, Volume 108, Issue 1, 1 July 1998, Pages 208-223</i> Charles A. Weber, John R. Current, Anand Desai <i>European Journal of Operational Research, Volume 90, Issue 1, 5 April 1996, Pages 142-155</i> Charles A. Weber, Anand Desai
Supplier selection and data envelopment analysis	1	0	

Scopus:

Supplier selection	1876		
Supplier selection and purchasing	206	9	<p>Ting, S.-C., Cho, D.I. (2008)</p> <p>Sarfaraz, A.R., Balu, R.(2007)</p> <p>Amid, A., Ghodsypour, S.H., O'Brien, C. (2006)</p> <p>Degraeve, Z., Labro, E., Roodhooft, F. (2005)</p> <p>De Boer, L., Labro, E., Morlacchi, P. (2001)</p> <p>Degraeve, Z., Roodhooft, F. (1999)</p> <p>Ghodsypour, S.H., O'Brien, C. (1998)</p> <p>Barbarosoglu, G., Yazgaç, T(1997)</p> <p>Weber, Charles A., Current, John R., Benton, W.C.(2001)</p>