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Electronic invoicing and digital archiving services: a provider selection model

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Ci sono attimi in cui tu
Folgorato
Penserai che tutto valeva la pena
Per arrivare a un giorno così.
Perfetto. Compiuto. Scintillante di gioia.
Da quel momento quell'attimo esiste.
Nel tuo tempo.
Nella tua eternità.
Per sempre.

INDEX

Index of Figures.....**V**

Index of Tables.....**VI**

Acronyms and Abbreviations.....**VII**

Abstract.....**VIII**

Riassunto.....**IX**

Executive Summary

I. Introduction X

II. Purpose XI

III. Methodology XI

IV. Model XI

V. Model Validation XII

VI. Results XII

Sommario

I. Introduzione XIV

II. Obiettivi XV

III. Metodologia XV

IV. Modello XVI

V. Validazione XVII

VI. Risultati..... XVIII

A - Reference Framework

1. Introduction 2

2. Supply Chain 3

3. Supply Chain Management 4

    3.1 Supply chain management definition 4

    3.2 Advantages, limitations and success factors 5

    3.3 Supply Chain Management policies and strategies 7

    3.4 Different integration solutions 8

    3.5 Supply chain 2.0 9

4. Supply Chain Management and data sharing 10

    4.1 role of Electronic Data Interchange in Data sharing 10

    4.2 Electronic Data Interchange Evolution: Internet-based data exchange 12

    4.3 Selection of the best solution 13

5. Conclusions 14

B - Literature Review

B.1 - Supplier Selection

1. Introduction and Framework 16
2. Supplier Selection problem 18
    - 2.1 Definition of supplier selection problem 18
    - 2.2 Factors affecting Selection Criteria 21
3. History of supplier selection problem 23
    - 3.1 Methodology 23
    - 3.2 General view 23
    - 3.3 Specific view 26
    - 3.4 Outsourcing of logistics activities 27
        - 3.4.1 Supplier selection problem for logistics activities 27
        - 3.4.2 3PL selection criteria 29
    - 3.5 Conclusions 30
4. Selection models 31
    - 4.1 Selection models classification 31
    - 4.2 Description of the main selection models 33
        - 4.2.1 Analytic Hierarchy Process (AHP) 34
        - 4.2.2 Analytic Network Process (ANP) 37
        - 4.2.3 Total Based Cost Approach 38
        - 4.2.4 Other minor methods 40
    - 4.3 Conclusions 41
5. Modern Works on Supplier Selection 42
    - 5.1 Methodology 42
    - 5.2 Supplier selection for Services 44
        - 5.2.1 Analytic Hierarchy Process 44
        - 5.2.2 Analytic Network Process, BOCR and Delphi Method 48
        - 5.2.3 Other works in service environment 50
    - 5.3 Supplier selection for material purchasing 52
        - 5.3.1 Analytic Hierarchy Process 53
        - 5.3.2 Analytic Network Process 56
        - 5.3.3 Other works in material environment 57
    - 5.4 Other relevant contributions 59
    - 5.5 Findings and Conclusions 60

B.2 - Electronic Invoicing, Integration and Dematerialization

1. Introduction 62
2. Traditional Invoicing Process 62

3. Electronic Invoicing and Dematerialization....65
3.1 Legal Framework....66
3.2 Electronic Invoicing security requirements....67
3.3 Benefits of Electronic invoicing....69
4. Electronic Invoicing Models....70
4.1 Definitions....70
4.2 Adoption paradigms....72
4.3 Service fruition modes....74
5. Electronic invoicing Market....75
5.1 Market Players....75
5.2 Supply Market....76
6. Adoption Barriers....77
7. Conclusions....78

C - Objectives and Methodology

1. Objectives....80
2. Framework....81
2.1 Analysis of the literature....82
2.1.1 Supplier selection....82
2.1.2 Electronic invoicing and digital archiving....84
2.2 Analysis of the Market....84
2.2.1 Structure of the interviews....84
2.2.2 Number, timing and companies....85
2.3 Model definition....86
2.3.1 Selection of the evaluation method....86
2.3.2 Steps for defining the model....87
2.3.3 Questionnaire for the pairwise comparison....88
3. The model....89

D - Analysis of the Market

1. Introduction....91
2. Key findings....91
2.1 Services offered....91
2.2 Evolution of users and clients....93
2.3 Typology of the clients....93
2.4 Pricing logics....94
3 Conclusions....94

E - The Model

1. Introduction and framework 97
2. Indexes definition 99
    - 2.1 Business 99
    - 2.2 Capabilities 109
    - 2.3 Cost 116
    - 2.4 Green and Environment 120
    - 2.5 Solution 122
3. Indexes selection 128
    - 3.1 Definition of the indexes' ranking 128
    - 3.2 Elimination of the worst indicators 130
    - 3.3 Elimination of the not-related dimensions 131
    - 3.4 Selection of the best ones 132
    - 3.5 Cost indexes 136
    - 3.6 Coverage checking 137
    - 3.7 Final Indexes selected 139
    - 3.8 Considerations on the selection process 140
4. Weights definition 140
5. Metrics 144

F - Model Validation

1. Validation Process 149
2. Definition and selection of the criteria 150
3. Definition of the weights 151

G - Findings and Conclusions

1. Innovativity of the model 157
2. Applicability of the model 157
3. Findings and comments 158
    - 3.1 Business, Solution, Capability and Green & Environment dimensions 158
    - 3.2 Cost dimension 160
4. Limits of the model 161
5. Future Researches 162

H - Example of Application

1. Companies and Performances 164
2. Cost assessment 166
3. Cost VS Performance Analysis 167

I - Annexes

1. History of supplier selection – Complete list of the indexes.....169
2. Modern works on supplier selection – complete list of the indexes 170
3. Complete interview's structure.....179

J - References 181

INDEX OF FIGURES

Figure 1 - Development Framework XIII
Figure 2 - Degrees of Supply Chain complexity. *Source: (Mentzer, et al., 2001)* 3
Figure 3 - Elements in the SCM framework. *Source: (COOPER, ET AL., 1997)* 5
Figure 4 - Supply Chain Management Strategies. *Source: (Lee, 2002)* 8
Figure 5 - Supply Chain Integration Views. *Source: (Fawcett & Magnam, 2002)* 9
Figure 6 - Depth of the collaboration and Solution type. *Source: (Pramatari, 2007)* 14
Figure 7 - Phases of supplier selection process and tasks in supplier selection. *Source: (Sonmez & Mahmut, 2006)* 21
Figure 8 - Factors affecting supplier selection criteria. Source: *SONMEZ & Mahmut, 2006* 22
Figure 9 - Environmental criteria model. *Source: (Humphreys, et al., 2003)* 26
Figure 10 - Comparison between Andersson and Jharkharia models. *Sources: (Andersson & Norrman, 2002; Jharkharia, 2007)* 28
Figure 11 - Example of AHP hierarchical structure. *Source: (Efendigil, et al., 2008)* 35
Figure 12 - AHP structure. *Source: (Saaty, 2004)* 38
Figure 13 - ANP structure. *Source: (Saaty, 2004)* 38
Figure 14 - Processes involved in the SCM Concept. *Source: (Lambert & Cooper, 2000)* 62
Figure 15 - Typical trade process. *Source: (Nienhuis & Bryant, 2010)* 63
Figure 16 - Distribution of physical invocies. *Source: (Nienhuis & Bryant, 2010)* 64
Figure 17 - The financial supply chain in a corporate environment. *Source: (Schaefer, 2010)* 64
Figure 18 - E-invoicing in the Trade process. *Source: (Observatory on Electronic Invoicing and Dematerialization, 2008)* 72
Figure 19 - Substitute Archiving adoption paradigm. *Source: (Observatory on Electronic Invoicing and Dematerialization, 2010)* 73
Figure 20 - Electronic Invoicing adoption paradigm. *Source: (Observatory on Electronic Invoicing and Dematerialization, 2010)* 73
Figure 21 - Full integration adoption paradigm. *Source: (Observatory on Electronic Invoicing and Dematerialization, 2010)* 74
Figure 22 - The Supply world. *Source: (Observatory on Electronic Invoicing and Dematerialization, 2008)* 76
Figure 23 - Development framework 81
Figure 24 - Example of the Questionnaire for the comparison 88
Figure 25 - Coverage checking 138
Figure 26 - Final Indexes selected 139

INDEX OF TABLES

Table 1 - Success and failure factors. *Source: (Elmuti, 2002)* 6
Table 2 - Classical EDI and web-based data sharing. *Source: (Pramatari, 2007)* 13
Table 3 - Classification of purchasing situations. *Source: (Faris, 1967)* 19
Table 4 - Purchasing portfolio matrix. *Source: (Kraljic, 1983)* 19
Table 5 - Dickson's and Weber's criteria. *Sources: (Dickson, 1966; Weber, 1991)* 24
Table 6 - Selection criteria according to the integration level. *Source: (Ghodsypour & O'Brien, 1998)* 25
Table 7 - Comparison between classification frameworks. *Source: (Sonmez & Mahmut, 2006; Aguezzoul, 2007; Yang & Chen, 2006; de Boer, et al., 2001)* 32
Table 8 - List and classification of decision making methods. *Source: (Sonmez & Mahmut, 2006) integrated with Yang (2006) and Aguezzoul (2007)* 33
Table 9 - Most Popular Selection Models. *Source: personal analysis and (Sonmez & Mahmut, 2006)* 34
Table 10 (following page) - Paper Classification 42
Table 11 - Pairwise Comparison Matrix for Business Category 141
Table 12- Normalized Matrix with Weight Definition for Business category 142
Table 13 - Final Weights Table 143
Table 15 - Capability final matrix 152
Table 14 - Solution final Matrix 153
Table 16 - Green & Environment Final Matrix 153
Table 17 - Business FInal Matrix 154
Table 18 - First LEvel Final Matrix 155
Table 19 - Example of Criteria Evaluation 165
Table 20 - Example of OveralL Ranking 165
Table 21 - Example of Evaluation for Supplier 1 165
Table 22 - Example of Evaluation for Supplier 2 165
Table 23 - Example of Evaluation For Supplier 3 166
Table 24 - Example of Cost Indexes 166
Table 25 - Example of Total Cost Calculation 167
Table 26 - Example of Cost/performance trade-off 167

ACRONYMS AND ABBREVIATIONS

Acronym	Meaning	Acronym	Meaning
3PL	Third Part Logistic	MFS	Make from Stock
ABC	Activity Based Costing	MIP	Mixed Integer Programming
AHP	Analytic Hierarchy Process	MOP	Multi-Objective Programming
AMQP	Advanced Message Queuing Protocol	MP	Mathematical Programming
ANN	Analytic Neural Network	MTO	Make to Order
ANP	Analytic Network Process	MTS	Make to Stock
BOCR	Benefits, Opportunities, Costs, Risks	PKI	Public Key Infrastructure
CA	Cluster Analysis	QFD	Quality Function Development
CA	Certification Authority	RA	Registration Authority
CBR	Case Based Reasoning	RFI	Request for Information
CoV	Coefficient of Variation	RFID	Radio Frequency Identification
CRP	Continuous Replenishment Program	RFP	Request for Proposal
CSMP	Council of Supply Chain Management Professionals	RST	Rough Set Theory
DEA	Data Envelopment Analysis	SC	Supply Chain
DM	Data Mining	SCM	Supply Chain Management
EDI	Electronic Data Interchange	SOAP	Simple Object Access Protocol
FMGC	Fast Moving Consumer Goods	TCO	Total Cost of Ownership
FPP	Fuzzy Preference Programming	TOPSIS	Technique for Ordering Preference by Similarity to Ideal Solution
GA	Genetic Algorithm	TSA	Time Stamping Authority
GDP	Gross Domestic Product	UDDI	Universal Description Discovery and Integration
GP	Goal Programming	VAN	Value Added Network
IWLA	International Warehouse Logistics Association	VAT	Value Added Tax
LW	Linear Weighting	VIKOR	VlseKriterijumska Optimizacija I Kompromisno Resenje (multi-criteria optimization and compromise solution)
MAUT	Multiple Attribute Utility Theory	VSP	Vendor Selection Problem
MCDM	Multi Criteria Decision Making		

ABSTRACT

Purpose: The adoption of dematerialization services in the everyday business is continuously growing. In particular, both business operators, looking for more efficient collaborations within the supply chain, and Governments, aiming at a more transparent economy, are pushing towards the adoption of digital-based solutions. Among all the potential services, a core role is played by electronic invoicing and digital archiving: electronic invoicing has been recognized as one of the most importance sources of productivity increase in Europe. The emerging of these solutions increased the number of companies belonging to the supply side of the market. This is a good point for potential customers, but rises also the problem of selecting the best supplier to rely on. The scope of this work is to identify which are the most important drivers to consider when evaluating a set of potential e-invoicing and digital archiving service providers. This paper provides a tool to support the decision maker during the evaluation process.

Research Approach: The research is based both on a broad literature review, and on a direct analysis of the supply market through phone interviews. The study relies also on the collaboration with the experts of the Observatory on Electronic Invoicing and Dematerialization of Politecnico di Milano. The criteria selected has been ranked by some of the main actors of the market.

Finding and Originality: The context of the analysis is new in the literature: no previous works on supplier selection for e-invoicing and digital archiving services have been found. The model developed is based on the application of the Analytic Hierarchy Process combined with a Total Cost approach. The results highlighted an higher interest towards suppliers with an easily and quickly implementable solutions. Great importance is given, also, to the performances on the supplier, in terms of flexibility, and financial stability. Limited care is put on the provider's internal dimensions and on environment respect issues.

Keywords: Supplier Selection, AHP, Electronic Invoicing, Digital Archiving.

RIASSUNTO

Scopo: Da qualche anno a questa parte, il mercato è testimone della proliferazione di servizi di dematerializzazione. In particolare, sia i Governi che le aziende più innovative, spingono verso queste soluzioni ambendo a un'economia più trasparente e ad una maggiore efficienza nel rapporto tra imprese. Esempi di tali soluzioni sono rappresentati dall'emissione, trasmissione e conservazione dei documenti fiscali in formato elettronico: Fatturazione Elettronica e Conservazione Sostitutiva sono stati infatti riconosciuti come due delle più importanti fonti di aumento della produttività in Europa. La diffusione di tali servizi ha portato sia alla nascita di nuove aziende, sia all'espansione del portafoglio servizi di altre; questo aumento dell'offerta porta con se, oltre agli aspetti positivi legati al meccanismo della concorrenza, anche risvolti negativi: i potenziali clienti di tali servizi si trovano a dover scegliere, senza alcuna esperienza, tra un gran numero di offerte apparentemente identiche. Lo scopo di questa ricerca è di identificare quali sono gli aspetti più importanti da considerare durante il processo di selezione di un fornitore di servizi di Fatturazione Elettronica e Conservazione Sostitutiva. Il risultato sarà quindi uno strumento di supporto durante il processo di valutazione.

Metodologia di ricerca: Questa ricerca ha basi sia letterarie che empiriche: l'analisi della letteratura è affiancata ad interviste telefoniche volte a mappare le aziende che offrono servizi di dematerializzazione. Forte è stata anche la collaborazione con gli esperti dell'Osservatorio sulla Fatturazione Elettronica e Conservazione Sostitutiva del Politecnico di Milano e le aziende partner: queste ultime, rappresentanti del mercato, hanno validato e classificato i criteri su cui si basa il modello.

Risultati e Originalità: Questa ricerca vuole colmare una lacuna identificata nella letteratura, applicando un modello di selezione a un ambito nuovo: l'offerta di servizi di Fatturazione Elettronica e Conservazione Sostitutiva. Tale modello combina l'Analityc Hierarchy Process con la valutazione del costo totale della soluzione. I risultati evidenziano che gli aspetti più importanti da considerare sono sia legati al prodotto, come la facilità di implementazione e la qualità, sia al fornitore stesso, come l'esperienza e alla solidità finanziaria.

Parole chiave: Fatturazione Elettronica, Conservazione Sostitutiva, AHP, Supplier Selection.

EXECUTIVE SUMMARY

I. INTRODUCTION

Nowadays, the need to reduce costs and faster the non-value adding operations, has pushed the attention of companies on dematerialization solutions. Furthermore, a second relevant cause of the diffusion of these kind of services is the growing pressure that Governments are putting in place to enhance a more transparent and efficient economy.

The term “dematerialization” is very general and can include several different solutions, among these, a central position is dedicated to electronic invoicing and digital archiving. These two solutions, are a core part of the more complex dematerialization of the trade process. In synthesis, electronic invoicing can be seen as the emission, transmission and receipt of an invoice that keeps a digital format for the whole process. While, on the other hand, digital archiving is the conservation in a digital format of the invoices.

The adaption of electronic invoicing and digital archiving can allow significant cost savings, especially if mixed with other integration solutions: in the most integrated example, the dematerialization of the whole process, from the emission of the order to its payment, the cost saving is quantified to be from 25 to 65 €/cycle.

On the other side of the market, the modification of the legal framework caused the proliferation of new dematerialization services: both new born companies, and already existing ones, enlarged their portfolio and begun to offer electronic invoicing and digital archiving as a service.

Given the nature of these solutions, many companies decided to outsource their processes, delegating the emission of the invoices and the consequent digital conservation to a supplier.

At this point, companies have to face with a new relevant problem: literature has spend a lot of efforts in defining the best way to evaluate a supplier for material purchasing , but few on supplier selection for services. Furthermore, given the relatively recent diffusion of dematerialization solutions, no previous works on supplier selection for dematerialization service have been completed. As a consequence, companies have to take the decision to outsource the management of sensitive data without previous experience nor a solid methodology.

The lack of a supplier selection methodology for electronic invoicing and digital archiving services, confirmed during the literature analysis, have led to the objective of this thesis.

II. PURPOSE

The objective of this thesis is to identify and evaluate which are the most important criteria to be considered when selecting a supplier for electronic invoicing and digital archiving services.

The results of this research is a ranked list of supplier selection criteria that are specifically thought for e-invoicing and digital archiving services. Using this model, the decision maker can rely on a solid and literature-driven methodology to evaluate a series of potential suppliers, compare this evaluation with the related total cost of each solution, and take the final decision.

III. METHODOLOGY

This research started with the analysis of the literature on two different issues. The first one is the literature on supplier selection (keywords: Supplier selection; Service outsourcing; Analytic Hierarchy Process; Outsourcing Provider Selection Model; Selection Model; Analytic Network Process) and the linked overview on the selection methods. The scope of this part was to derive the most used indexes used to solve the supplier selection problem.

The second issue is the literature on dematerialization services (keywords: dematerialization; e-invoicing; digital archiving; trade process integration). The purpose of this part was to consolidate the knowledge on e-invoicing and digital archiving, so that the indexes identified in the literature could be selected for the specific case.

The analysis of the literature was integrated with a direct analysis of the market, made by the author by phone interviews to the main market players. The scope of this analysis was to understand the configuration of the supply side of the dematerialization market as long as the general composition of the customers.

The evaluation of the most important dimensions, related to the general performances, was performed applying the Analytic Hierarchy Process (AHP). On the other side, the cost dimension are quantified with a Total Cost model.

IV. MODEL

The model was based on the indexes derived from the literature analysis and where selected thanks to the knowledge created in the analysis of the market and of the literature on dematerialization.

In order to provide this selection, an evaluation algorithm, based on the specific relevance of each criterion, has been applied.

The result were a set of 38 second-level indexes, grouped in 5 first-level categories: *Business*, *Solution*, *Capabilities*, *Green & Environment* and *Costs*.

The indexes belonging to the first 4 dimension, were then analyzed and used to create a series of pairwise comparisons, that was the basis of the AHP model. On the other hand, the Costs indexes were combined with a Total Cost approach. In this way, the evaluation derived from the AHP model can be compared with the Total Cost of the solution, enabling the decision maker to perform a quality versus cost analysis.

The complete framework of the research can be seen in the following figure.

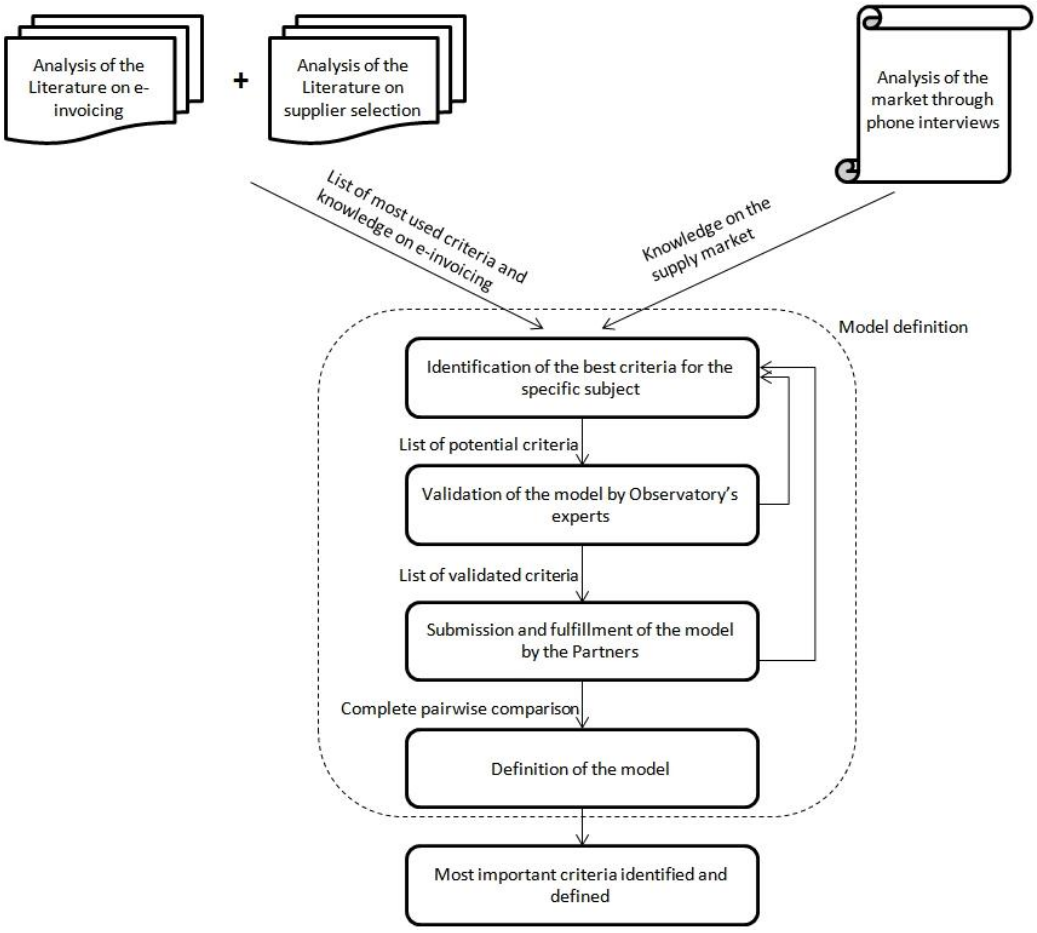


FIGURE 1 - DEVELOPMENT FRAMEWORK

V. MODEL VALIDATION

A model developed without a consistent validation is not reliable. For this reason, during the definition process, different validation steps have been undertaken.

The first one derives from the collaboration with the experts of the Observatory on E-Invoicing and Digital Archiving of the Politecnico di Milano and was applied just after the selection of the indexes in order to validate them. Furthermore, these indexes were previously selected analysing a wide literature with high Impact Factors.

Once the set of indexes was ready, the weights were derived sending a questionnaire to the main partners of the Observatory. This wide community includes some of the main representatives belonging to the different sectors involved in the supply of dematerialization services (banks, service providers, postals, printers and EDI providers) as long as clients' organizations. Note that this validation had a twofold impact: one is the definition of the ranks, and the other one is a further validation of the indexes since, if a criterion was considered not useful, it would receive a very low grade.

The final validation point derives from the analysis of the comparison matrixes: before calculating the final results, for each matrix the Consistency Ratio has been computed, and the ones not respecting Saaty's (1980) requirements have been eliminated. Once the final matrix has been derived, the consistency check has been done again.

VI. RESULTS

As regards the application of the AHP, the evaluation of the indexes highlighted some interesting aspects. First of all, there is a predominance of the *Solution* (59.92%) category over the others: *Capability* (22.00%), *Business* (13.23%) and *Green & Environment* (4.85%).

This ranking underlines the attention of the decision maker on the more service-related dimensions, and it is easily agreeable considering that the application context referrers to the supplier selection for service purchasing. Within this dimension, the most important aspects are related to the easiness to implement the solution, both directly related to the solution itself (*Implementability* – 26.66%), and to the efforts required by the implementation project (*Project* – 21.42%). High relevance is also dedicated to the *Service quality* (20.32%), while the characteristics of the solution and the customer service have medium importance.

As regards the *capability* category, the most important aspect to be considered is the *flexibility* of the company (52.34%) followed by internal *Financial status* (21.25%), *Managerial ability* (18%) and *Technological level* (8.40%).

When referring to the general characteristics of the potential supplier, an predominant position is played by the experience of the candidate: *Specific Experience* (19.17%) and *Market knowledge* (16.12%). A relevant importance is dedicated also on the overall economical stability and the reputation of the company. Little attention is reserved for the internal characteristics of the supplier.

Poor attention is paid for the green aspects of the enterprise: *Emission level* and *Environmental saving policies* are worth, together, only the 4.85% of the total (equally distributed).

On the cost side, the research depicted 11 main cost dimensions to be considered when calculating the total cost of the solution. These indexes include four main aspects: the *price* of the solution, the implementation costs (*customization* and *training*), the cost necessary to run the operations and maintain the relationship (*relationship costs*; *maintenance costs*; *compliance costs*; *cost of upgrades*; *minimum fee*) and other considerations on the payment terms (*discount flexibility*; *terms of contract*). While the first two dimensions are easily quantifiable in terms of €/page or €/year, the last two dimension are more difficult to quantify and may need feedbacks from other companies.

All these results have been included in a specific tool available for companies. Using this instrument, the decision maker just have to insert the grades for each criteria and the cost data, and it will automatically calculate the ranking for each category, the total one, and the overall cost of the solution. The results are improved with a graphical representation that will facilitate the interpretation.

SOMMARIO

I. INTRODUZIONE

Il mercato attuale è testimone della crescente diffusione di servizi di dematerializzazione; tale aumento è riconducibile alla necessità di ridurre costi e tempi dedicati a servizi a basso valore aggiunto, ma assolutamente non eliminabili, come l'emissione e la conservazione dei documenti fiscali. D'altro canto, forte è anche la pressione esercitata dal Governo per favorire un'economia più trasparente e aumentare l'efficienza dei rapporti tra aziende e Pubblica Amministrazione.

Con il termine "dematerializzazione" si includono svariate soluzioni, tra cui la Fatturazione Elettronica e la Conservazione Sostitutiva; questi ultimi servizi possono essere brevemente descritti come "*lo scambio di fatture elettroniche firmate digitalmente e riferite temporalmente, a cui segue la conservazione sempre in formato digitale*" (Observatory on E-Invoicing and Digital Archiving, 2007).

L'adozione della Fatturazione Elettronica e della Conservazione Sostitutiva può ridurre sensibilmente tempi, e di conseguenza costi, legati alla gestione del ciclo di vita dell'ordine, soprattutto se ad essi si affiancano soluzioni di integrazione coi fornitori e clienti. I vantaggi più rilevanti, quantificati dall'Osservatorio sulla Fatturazione Elettronica e Conservazione Sostitutiva, sono variabile da 25 a 65 € a ciclo, e si riferiscono alla completa dematerializzazione del ciclo ordine-pagamento (dall'emissione dell'ordine al pagamento dello stesso).

La diffusione di tali servizi vede, inoltre, un parallelo mutamento del mercato dell'offerta: sia nuove realtà, sia azienda pre-esistenti hanno incluso servizi di dematerializzazione nel loro portafoglio. In questo modo, aziende prima appartenenti a settori differenti come banche e operatori postali, si trovano ora a competere in un nuovo mercato.

L'incertezza sulla normativa, la necessità di investire in nuove tecnologie e di modificare i sistemi informativi aziendali, hanno portato molte aziende a ricorrere all'outsourcing per i servizi di Fatturazione Elettronica e Conservazione Sostitutiva. Questa logica, pur facilitando l'utilizzo e riducendo i costi, comporta la necessità di selezionare un fornitore.

Nel passato, la letteratura si è focalizzata molto sul tema della selezione dei fornitori per l'acquisto di beni materiali, come materie prime o semilavorati, e ha prestato poca attenzione al mondo della selezione di fornitori di servizi; inoltre, all'interno di questa limitata realtà, nessun lavoro è mai stato riferito alla selezione di fornitori di servizi di dematerializzazione. La conseguenza diretta di questa lacuna è che le aziende si trovano a dover affidare processi riservati, con informazioni sensibili come

fatture, buste paga, ricevute di pagamento e altri documenti fiscali, a fornitori senza un processo di selezione strutturato e validato dal mondo accademico. Molte aziende, inoltre, a causa della natura relativamente recente di questi servizi, non hanno alcuna esperienza a cui affidarsi in questo ambito.

La necessità di colmare questa lacuna è, quindi, la causa principale della scelta dell'argomento di questa tesi.

II. OBIETTIVI

L'obiettivo di questa tesi è di identificare quali sono i criteri più importanti da considerare durante il processo di valutazione dei potenziali fornitori di servizi di Fatturazione Elettronica e Conservazione Sostitutiva.

Il risultato di questa ricerca è un modello che, basandosi su un set di indici appositamente pensati per tali servizi, consente di valutare in modo completo i potenziali fornitori.

Utilizzando questo modello, il decision maker può basare la propria scelta su un processo con solide basi sia letterarie, sia empiriche, validato dal giudizio di esperti, che permette di valutare le performance generali dei canditati e propone un confronto con il costo totale della soluzione offerta.

III. METODOLOGIA

Questa ricerca ha inizio con l'analisi della letteratura su due argomenti principali. Il primo è il tema della Supplier Selection (keywords: Supplier selection; Service outsourcing; Analytic Hierarchy Process; Outsourcing Provider Selection Model; Selection Model) affiancato da una analisi sui modelli di valutazione disponibili. Lo scopo di questa sezione è di derivare una lista di indici maggiormente usati nel contesto della selezione dei fornitori.

Il secondo tema è legato alla dematerializzazione e ai servizi ad essa connessi (keywords: dematerialization; e-invoicing; digital archiving; trade process integration). Lo scopo di questa sezione è di raccogliere e consolidare la conoscenza disponibile sui servizi di Fatturazione Elettronica e Conservazione Sostitutiva, per poi applicarla al processo di selezione e scrematura degli indici.

L'analisi della letteratura è inoltre integrata con un'analisi diretta del mercato dell'offerta svolta dall'autore mediante interviste telefoniche. L'obiettivo di queste interviste è di capire la configurazione del mondo dell'offerta di servizi di dematerializzazione e dedurre un'idea generale sulla composizione dei clienti.

La valutazione delle dimensioni principali sulle performance generali del fornitore si basano sull'applicazione di un Analytic Hierarchy Process (AHP), mentre la quantificazione del costo della soluzione è basata sul calcolo del costo totale.

IV. MODELLO

Lo schema di riferimento seguito può essere visto nella figura che segue.

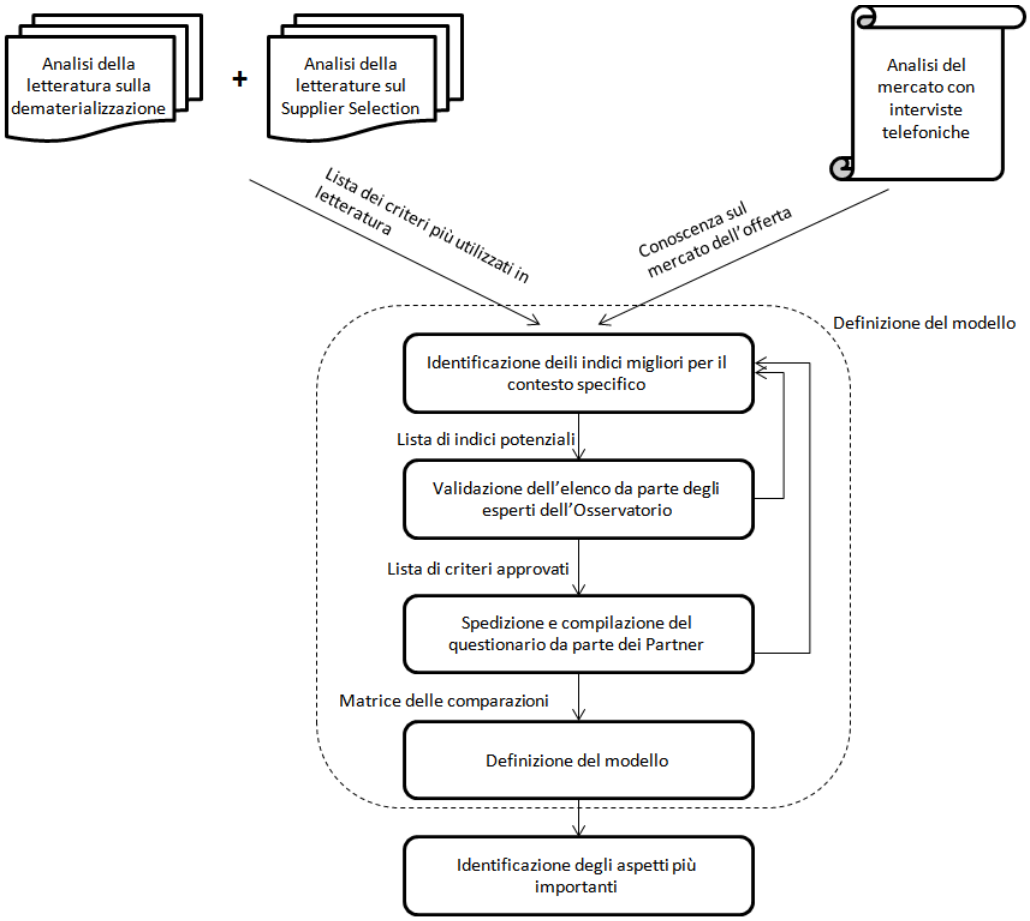


FIGURA 1A – SCHEMA DI RIFERIMENTO

In particolare, il modello è basato sugli indici derivanti dalla letteratura e selezionati grazie alla conoscenza acquisita durante l'analisi del mercato e della letteratura sui servizi di dematerializzazione.

Per svolgere questa selezione, inoltre, si è ricorso a un modello basato sull'importanza specifica di ogni singolo indice. Questo processo ha portato alla selezione di 38 indici di secondo livello e 5 di primo livello (denominati "categorie"): *Business, Solution, Capabilities, Green & Environment* e *Costs*.

Gli indici appartenenti alle prime quattro categorie sono stati analizzati tramite una serie di comparazioni a coppie, che rappresentano la base del modello AHP. Per quanto riguarda la

dimensione costo invece, il calcolo del costo della soluzione è basato sulla logica del Costo Totale. In questo modo il modello permette una doppia analisi: da un lato è possibile confrontare i fornitori valutandone le performance totali o il costo della soluzione, dall'altro lato è possibile anche eseguire un'analisi di trade-off tra costo e prestazione.

V. VALIDAZIONE

Il modello definito sarebbe inutilizzabile se non fosse stato validato da adeguati controlli. Per questo motivo, durante il processo, sono state eseguite diverse validazioni.

La prima è stata sostenuta dopo aver selezionare gli indici su cui sarebbe stato basato il modello: gli esperti dell'Osservatorio sulla Fatturazione Elettronica e Conservazione Sostitutiva del Politecnico di Milano hanno controllato e approvato il set di indici. Bisogna considerare, inoltre, che i criteri di valutazione sono stati derivata dall'analisi di una ampia letteratura con elevati Impact Factors.

Il secondo step di validazione è rappresentato dall'interazione con i partner dell'Osservatorio: in particolare a queste aziende è stato chiesto di compilare un questionario contenente le comparazioni a coppie su cui si basa l'Analytic Hierarchy Process. La comunità dei partner dell'osservatorio annovera aziende di tutti i settori coinvolte nell'offerta di servizi di dematerializzazione (banche, postali, stampatori, fornitori di servizi e di soluzioni EDI), insieme a una rappresentanza delle maggiori associazioni di filiera (appartenenti principalmente al mondo della grande distribuzione, farmaceutico, contabile e bancario). Bisogna notare, inoltre, che questo processo di comparazione funge come controllo ulteriore della bontà degli indici selezionati: se un criterio non fosse considerato adeguato, riceverebbe una votazione molto bassa, e il conseguente peso sarebbe talmente ridotto da rendere l'indice irrilevante.

L'ultimo step di validazione è stato svolto durante la definizione dei pesi. Infatti, prima di derivare la matrice di comparazione finale, ogni singolo contributo è stato analizzato e convalidato calcolando il rapporto di consistenza ed eliminando quelli che non soddisfavano i requisiti espressi da Saaty (1980). La matrice finale, derivata dalla media delle singole valutazioni, è stata sottoposta nuovamente a questo processo di validazione.

VI. RISULTATI

Per quanto riguarda il modello AHP, la valutazione degli indici ha evidenziato aspetti interessanti. Prima di tutto, a livello di categorie (primo livello) si nota una predominanza della dimension *Solution* (59.92%) rispetto alle altre: *Capability* (22%), *Business* (13.23%) e *Green & Environment* (4.85%).

Questo dato sottolinea l'attenzione dell'utente alle grandezze direttamente riferite alla valutazione della soluzione, ed è facilmente condivisibile considerando che il contesto di analisi è la valutazione di fornitori per l'acquisto di servizi. All'interno di questa dimensione, detengono un ruolo rilevante le grandezze riferite alla facilità di implementazione (*Implementability* – 26.66%) e all'impegno richiesto dal progetto per introdurre la soluzione stessa (*Project* – 21.42%). Notevole importanza è attribuita, inoltre, alle qualità della soluzione stessa (*Service quality* – 20.32%).

Riguardo alla dimensione *Capability* (che include la valutazione delle capacità del fornitore), l'aspetto più importante da considerare nella selezione è la *flessibilità* (53.34%), seguita dalle *performance finanziarie* (21.25%) e dall'*abilità del management* (18%). Facendo riferimento invece alle dimensioni generali del fornitore (categoria *Business*), si nota una predominanza degli aspetti riferiti all'esperienza (*Specific Experience* – 19.17% e *Market Knowledge* – 16.12%) e alla stabilità economica del candidato (*Volumes of business* – 13.41% ed *Economic status* – 12.12%). Media importanza è attribuita, inoltre, alla *reputazione* (7.16%).

Scarsa attenzione è stata data agli aspetti più Green dell'impresa: il livello di emissioni e le politiche di tutela dell'ambiente valgono insieme il 4.85% del totale (equamente distribuito).

Per quanto riguarda i costi, la ricerca ha evidenziato undici principali dimensioni da considerare nel calcolo del costo totale. Questi indici coprono quattro aspetti principali: il prezzo della soluzione, i costi di implementazione (personalizzazione e formazione del personale), i costi necessari per mantenere la relazione e usufruire del servizio (costi di relazione, manutenzione, aggiornamento e tariffa minima) e altri costi legati alle condizioni di pagamento (sconti per alti volumi e vincoli contrattuali).

Mentre il prezzo della soluzione e il costo dell'implementazione sono facilmente esprimibili in termini di € per pagina o € all'anno, la quantificazione delle ultime due dimensioni non è così immediata. Per quanto riguarda i costi di utilizzo e di mantenimento della relazione, l'azienda dovrà far riferimento all'esperienza posseduta in altri contesti o, se ne ha la possibilità, chiedere dei feedback ad aziende che già usufruiscono di tali servizi. Riguardo alle condizioni di pagamento, infine, lo sconto per alti volumi può essere facilmente incluso del costo del servizio, mentre i vincoli contrattuali, se presenti, possono essere espressi come penali o costi *una tantum*.

Questi risultati sono stati raccolti in uno specifico foglio di calcolo. In questo modo l'utente deve solamente inserire la votazione per ogni criterio e i gli indici di costo; lo strumento calcolerà automaticamente l'indice di performance per le quattro categorie, la valutazione totale e il costo della soluzione. L'interpretazione dei risultati sarà facilitata da una rappresentazione grafica degli stessi.

A. REFERENCE FRAMEWORK

SUPPLY CHAIN, SUPPLY CHAIN MANAGEMENT AND DATA SHARING

In this section I will explain the context in which this research work is included. In particular, the concept of supply chain and supply chain management will be analyzed, explaining the different definitions and management practices proposed in the literature, and pointing out the success and failure factors. A further attention will be dedicated to the importance of data sharing within business-to-business context, with a special focus on the EDI technology.

1. INTRODUCTION

The contest in which companies operate has changed a lot in the last decades: business actors have to face with an increased competition, globalization, several technological changes, and more demanding customers. For several years, the proponents of Supply Chain Management (SCM) principles argued that the very nature of competition is changing: companies will no longer compete against other companies, but supply chains will compete against other supply chains for market supremacy (Fawcett & Magnam, 2002).

A full integration of procurement processes, invoicing and payments along the physical and financial supply chain is an essential driver for enterprise costs saving (Salmony & Harald, 2010). Supply Chain Management (SCM) as a concept, is now well established, and its adoption has helped many firms to gain a competitive edge (Christopher & Holweg, 2011).

In particular, SCM seeks at enhancing competitive performance by a close integration of the internal functions within a company and effectively linking them with the external operations of suppliers and channel members. SCM works to bring the supplier, the distributor, and the customer into one cohesive process (Elmuti, 2002). In few words, it can be stated that an underlying principle of SCM is to establish control of the end-to-end process in order to create a seamless flow of goods (Christopher & Holweg, 2011).

Below are the main drivers enhancing SCM concept (Mentzer, et al., 2001).

- ✓ *Global sourcing*: the globalization of supply has forced companies to look for more effective ways of coordinate the flows of materials inwards and outwards the company. The key to obtain such coordination are closer relationships with suppliers.
- ✓ *Emphasis on time and quality-based competition*: getting a defect-free product to the customer faster and more reliably than the competition is no longer seen as a competitive advantage, but a simple requirement by the market.
- ✓ *Marketplace uncertainty*: global orientation and increased performance-based competition, combined with rapidly changing technology and economic conditions, contributed to increase marketplace uncertainty. This uncertainty requires greater flexibility both in the company and in the supply chain.

2. SUPPLY CHAIN

Before talking about SCM, the concept of Supply Chain has to be clarified. Scholars had given different possible definitions of supply chain:

- La Londe & Masters (1994) proposed that a supply chain is a set of firms that pass materials forward (La Londe & Masters, 1994);
- Lamber, et al. (1998) defined supply chain as the alignment of firms that brings products or services to the market (Lambert, et al., 1998);
- Christopher (1992) noted that a supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services related to the ultimate consumer (Christopher, 1992).

Collecting these definitions, Mentzer, et al. (2001) defined Supply Chain as:

> A SET OF THREE OR MORE ENTITIES (ORGANIZATIONS OR INDIVIDUALS) DIRECTLY INVOLVED IN THE UPSTREAM AND DOWNSTREAM FLOWS OF PRODUCTS, SERVICES, FINANCES, AND/OR INFORMATION FROM A SOURCE TO A CUSTOMER (MENTZER, ET AL., 2001).

Mentzer, et al. (2001) also identified 3 main degrees of supply chain complexity (Figure 2).

1. *Direct supply chain*: it consists of a company, a supplier and a direct customer involved in the flow of products, services, finances or information.
2. *Extended supply chain*: it includes in the chain the suppliers of the direct supplier and the customer of the immediate customer. All these actors are involved in the flows.
3. *Ultimate supply chain*: it includes all the organizations and entities involved in the flows, from the ultimate supplier to the ultimate customer.

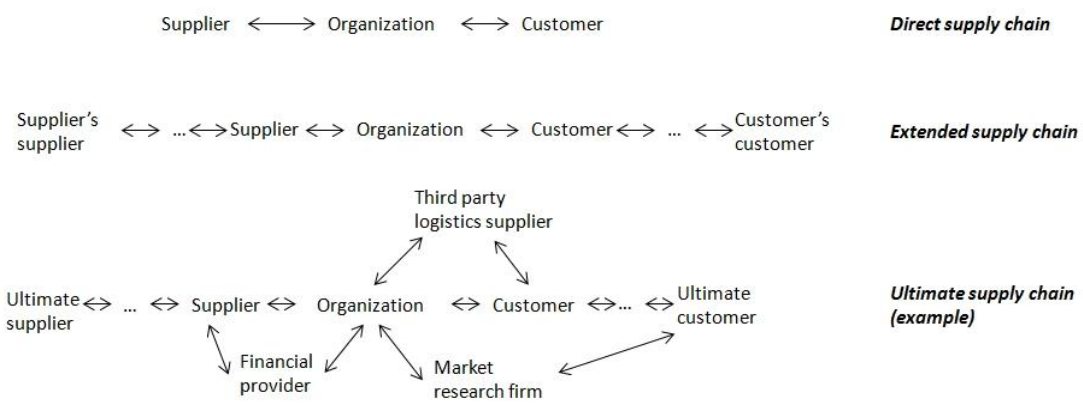


FIGURE 2 - DEGREES OF SUPPLY CHAIN COMPLEXITY. *SOURCE: (MENTZER, ET AL., 2001)*

3. SUPPLY CHAIN MANAGEMENT

3.1 SUPPLY CHAIN MANAGEMENT DEFINITION

When talking about SCM, two important considerations have to be done.

First, it has to be stated that the supply chain exists independently whether it is managed or not. For this reason a definite distinction has to be set between supply chains seen as phenomena that exist in businesses, and the management of those supply chains (Mentzer, et al., 2001).

Second, the distinction between Supply Chain Orientation and Supply Chain Management as to be clarified: the first concept can be defined as "*the recognition by an organization of the systemic, strategic implications of the tactical activities involved in managing the various flows in a supply chain*", while the second one is the actual and shared implementation of the Supply Chain Orientation across suppliers and customers (Mentzer, et al., 2001).

Having clarified these two points, the current definition of the Council of Supply Chain Management Professionals (CSCMP) is the following (CSCMP, s.d.):

> SUPPLY CHAIN MANAGEMENT IS AN INTEGRATING FUNCTION WITH PRIMARY RESPONSIBILITY FOR LINKING MAJOR BUSINESS FUNCTIONS AND BUSINESS PROCESSES WITHIN AND ACROSS COMPANIES INTO A COHESIVE AND HIGH-PERFORMING BUSINESS MODEL. IT INCLUDES ALL OF THE LOGISTICS MANAGEMENT ACTIVITIES, AS WELL AS MANUFACTURING OPERATIONS, AND IT DRIVES COORDINATION OF PROCESSES AND ACTIVITIES WITH AND ACROSS MARKETING, SALES, PRODUCT DESIGN, FINANCE, AND INFORMATION TECHNOLOGY.

It has to be noticed though, that according to a research done by Fawcett & Magnam (2002), managers from functional areas not only define Supply Chain Management in different and varied ways, but they also view the integrative nature of Supply Chain Management differently (Fawcett & Magnam, 2002).

The definition also reflects the SCM framework proposed by Cooper, et al. in 1997; according to this framework, SCM consists of 3 main and closely related elements (Figure 3): *business processes* (activities that produce a specific output of value to the customer), *management components* (components by which the business processes are structured and managed), and *supply chain structure* (configuration of companies within the supply chain) (Cooper, et al., 1997).

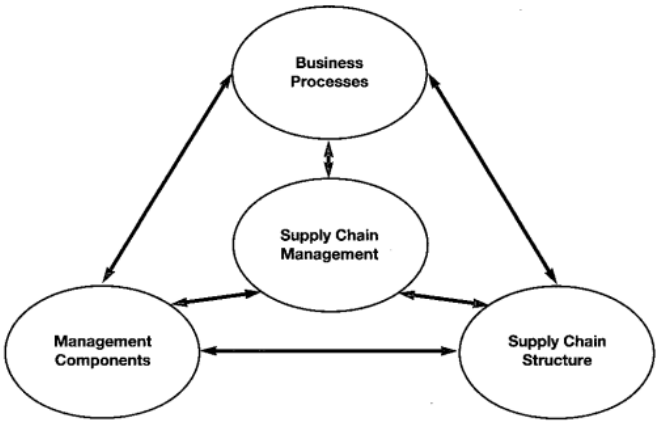


FIGURE 3 - ELEMENTS IN THE SCM FRAMEWORK. *SOURCE: (COOPER, ET AL., 1997)*

3.2 ADVANTAGES, LIMITATIONS AND SUCCESS FACTORS

When considering whether to undertake a SCM project or not, decision makers have to consider several factors. According to literature, the top reasons for undertaking SCM projects are (in order of importance): reduce costs, inventory and cycle time, improve quality, improve delivery, reliability and customer service, use resources that are not available internally, increase productivity, establish a presence in a new market and/or increase market share, maintain a sufficient flexibility to respond to market conditions, efficient use of human resources, make capital funds available for more profitable operations, focus on core competences and profitability, and gain competitive advantages over competitors. Elmuti (2002) tried also to define which of the specific objectives of the SCM implementation have actually been reached. The results showed that the majority of the companies considered (56%), has improved in performances, cost saving, productivity, cycle time and customer care. It has to be noticed though, that the improvement obtained has generally been lower than the expected: while organizations are not getting the projected improvements in all the supply chain, they are achieving significant improvements in their internal activities. One reason for this misalignment can be traced back to unclear goals or expectations (Elmuti, 2002).

The benefits deriving from an active SCM policy are underlined also by other academic papers: companies that successfully used SCM techniques to integrate manufacturing, distribution, marketing and sales, as a result have created substantial savings on inventories, costs, have improved service (Mainardi, et al., 1999), increased profitability and productivity (Gryna, 2001) and reduced risk (Chase, et al., 2000).

As already said before, the achievement of the targeted goals expected from the SCM policy implementation is not a certain fact. In particular the variability that reduces the performances of the supply chain can derive from a wide range of factors: *demand side* (shifts in customer demand for product), *supply side* (hikers in steel, copper and gold prices), *regulation* (shift in consumer

perception towards climate change), *political* (opening of markets and growth of East Asia or regional conflicts), *energy costs* (oil, gas and electricity prices), *financial* (exchange rates, currency fluctuation and availability of credit), and *technology* (shifts in dominant designs and disruptive innovations) (Christopher & Holweg, 2011).

In 2004, Lee analyzed more than 60 different supply chains, and suggested that, to achieve a sustainable competitive advantage, the supply chain needs all the following three qualities:

- ✓ *Agility* – respond to short-term changes in demand or supply quickly;
- ✓ *Adaptability* – adjust supply chain design to accommodate market changes;
- ✓ *Alignment* – establish incentives for supply chain partners to improve performance of the entire chain.

The different factors that can make the difference between a successful implementation of an SCM project, and an unsuccessful one, have been identified by Elmuti (2002) and can be seen in the following table.

Successful organizations	Unsuccessful organizations
• Integrated behavior between customer and supplier • Information sharing with all levels of supply chain • Cooperation throughout the supply chain • Clear objectives and expectations by all parties in the chain • Integration of processes of supply chain activities • Establishing partnerships • Mutually sharing channel risks and rewards.	• Lack of cooperation within supply chain activities • Lack of information sharing • Lack of integration in behavior and functions • Lack of trust and partnership • Lack of sharing channel risks and rewards lack of long-term commitment • Lack of same goals and focus of serving customers.

TABLE 1 - SUCCESS AND FAILURE FACTORS. *SOURCE: (ELMUTI, 2002)*

As can be seen in the **Error! Reference source not found.**, the main success factors can be also the main reasons for failures. Among all these dimensions, a particular attention has to be dedicated to the alignment between customer and supplier. For this reason, most successful companies created alignment in supply chain in several ways. The starting point is the alignment of information, so that all the companies in a supply chain have equal access to forecasts, sales data, and plans. Next the alignment of the identities comes: in other words, the manufacturer must define the roles and responsibilities of each partner so that there is no scope for conflict. Then companies must align incentives, so that when companies try to maximize returns, they also maximize the supply chain's performance. To ensure that this maximisation actually happens, companies must try to predict the

possible behaviour of supply chain partners in the light of their current incentives. Companies have to predict what their partners will do and how they would react in the same way as they do with competitors (Lee, 2004).

3.3 SUPPLY CHAIN MANAGEMENT POLICIES AND STRATEGIES

Analyzing and interviewing several companies, Fawcett & Magnam (2002) defined 3 levels of SCM practices:

1. *SCM as application of information technologies to help increase the quality of information and speed in exchange among channel members* - This practice is very attractive but not enough to meet targeted results.
2. *SCM as a practice to manage a set of fundamental building blocks that lead to closer channel relationships* - The core building blocks include linked information systems, integrative inter-organizational processes, aligned goals, consistent measures, shared risks and rewards, and cross-experienced managers.
3. *SCM as a cultural orientation or philosophy that guides decision making* - It promotes the building up of a world-class supply chain team through the selection of the right team members and the establishment of appropriate relationships. Two components are critical at this level: supply chain design and supply chain integration.

In order to give a more detailed classification of the possible SCM strategies, the "uncertainty framework" has to be introduced. This framework identifies two main types of uncertainty related to a product: *demand* and *supply*.

On the demand side, uncertainty is linked to the predictability of the demand for the product. For example, functional products (basic food, oil and gas, basic clothing) have a more stable demand if compared to innovative ones (fashion apparel, high-tech computers, mass customized goods). On the supply side, the uncertainty depends on the level of stability of the supply chain: a supply chain in which the manufacturing process and the underlying technology are mature and the supply based is well established can be considered stable, while an evolving supply chain, in which technology and process are under development and rapidly changing is more unstable and unpredictable.

Combining these 2 dimensions, Lee (2002) identified the following 4 strategies (Figure 4):

- *efficient supply chains* – focused on highest cost efficiency, eliminating non-value-added activities, pursuing economies of scales on optimization;

- *risk-Hedging supply chains* – utilizes strategies aimed at pooling and sharing resources in a supply chain so that the risk in supply distribution can be shared;
- *responsive supply chains* – utilizes strategies aimed at being responsive and flexible to the changing in diverse needs of the customers;
- *agile supply chains* – utilized strategies aimed at being responsive and flexible to customer needs, while the risk of supply shortages or disruption are hedged by pooling inventory or other capacity resources.

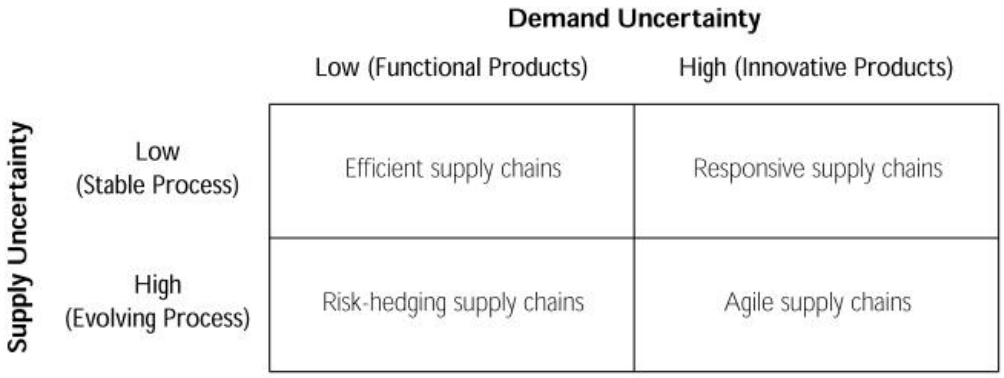


FIGURE 4 - SUPPLY CHAIN MANAGEMENT STRATEGIES. *SOURCE: (LEE, 2002)*

3.4 DIFFERENT INTEGRATION SOLUTIONS

The integration of different companies in one cohesive supply chain can reach different levels, ranging from "cross-functional process integration within the firm" to "complete forward and backward supply chain integration". Fawcett & Magnam (2002) identified the 4 main types of supply chain integration (Figure 5) listed below.

- *Internal cross-functional integration* – It is the integration of the processes inside the company. It was identified as the crux of supply chain initiatives.
- *Backward integration* – It is the integration with the first-tier suppliers. This was identified by Fawcett & Magnam (2002) as the most frequent supply chain integration model.
- *Forward integration* – Integration with the first-tier customers.
- *Complete forward and backward integration* – This integration solution expresses and integration from the "supplier's supplier to the customers' customer". This type of configuration was very rare and was more a theoretical ideal.

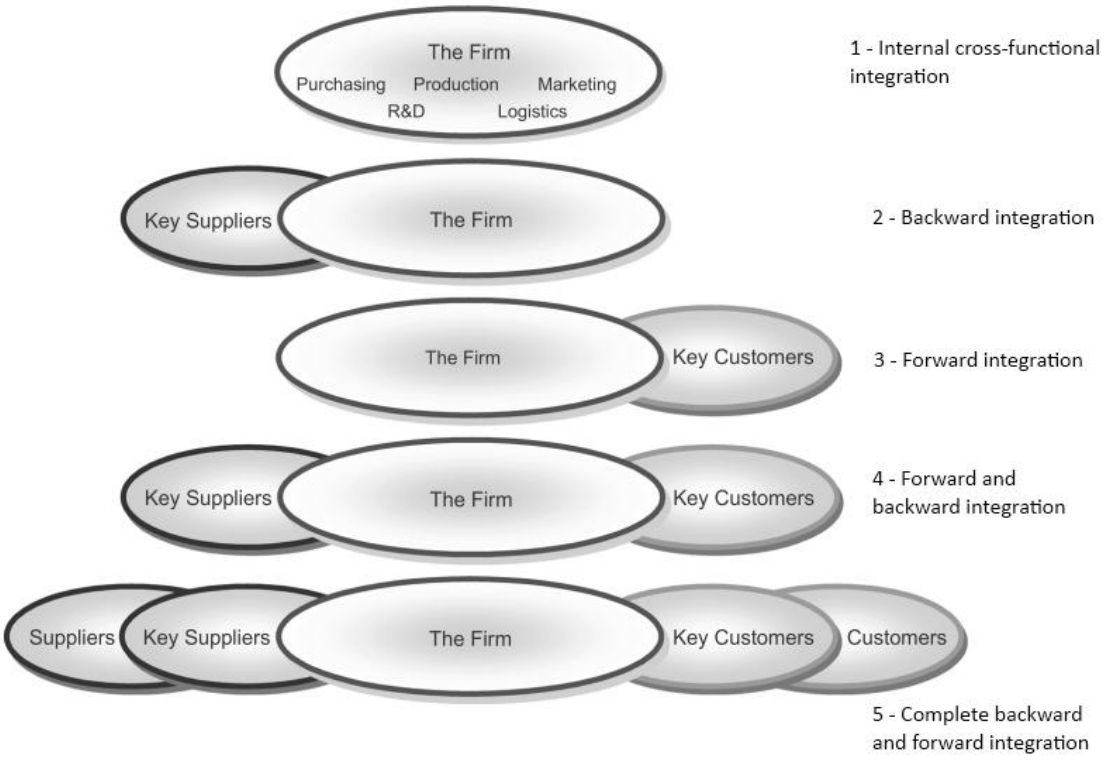


FIGURE 5 - SUPPLY CHAIN INTEGRATION VIEWS. *SOURCE: (FAWCETT & MAGNAM, 2002)*

3.5 SUPPLY CHAIN 2.0

In 2011, Christopher & Holweg stated that all the current SCM models have been invented during a long period of relative stability. However, this assumption of stability no longer holds: structural flexibility[1] that builds flexible options into the design of supply chain is needed to meet the challenges of a turbulent business environment.

Global market turbulence idea is not new among academics, but Christopher & Holweg developed the Supply Chain Volatility Index[2] to explain why the current situation is different from the past. The results underline that, differently from the past, nowadays the business is facing a big variation in several factors all together (financial, raw materials, stock market and shipping costs). For this reasons the old SCM process will need a rethinking (Christopher & Holweg, 2011).

[1] Structural flexibility refers to the ability of the supply chain to adapt to fundamental changes in the business environment (Christopher & Holweg, 2011).
[2] The index is based on the coefficient of variation (CoV) as a normalized and scale-free measurement of volatility. The indicators included in the model were referred to financials, raw materials, stock price and shipping costs Christopher & Holweg, 2011).

4. SUPPLY CHAIN MANAGEMENT AND DATA SHARING

Since the early 1990s, there has been a growing understanding that SCM should be built around the integration of trading partners (Barratt & Oliveira, 2001). In order to facilitate this integration, and carry out effective and efficient transactions, a fluent and linear flow of information between parties is crucial (Stefansson, 2002).

A great role in enabling these types of collaborations and information flows is played by Information technology (IT). Furthermore, there is a clear evolution path in the capabilities and sophistication of the underlying IT infrastructure supporting former versus later forms of collaboration (Pramatari, 2007). In order to provide effective support for the functioning of the logistics and information channels, the overall information systems architecture must be capable of linking and coordinating the information systems of the individual parties into e cohesive one (Stefansson, 2002).

The benefits obtained by the usage of advanced technology and data sharing techniques are mainly linked to the increase of resource utilization and thus the reduction of costs (Martin, 1994). In fact, establishing electronics links with suppliers and customers enables companies to transmit and receive purchase orders, invoices and shipping notifications with much shorter lead times than previously, which gives potential to speed up the entire shipping transaction (Muprhy, 1998).

For example, in retailing and fast moving consumer goods (FMCG), supply chain collaboration has mainly taken form of practices such as continuous replenishment program (CRP), vendor managed inventory (VMI), and collaborative planning, forecasting and replenishment (CPFR) (Pramatari, 2007).

4.1 ROLE OF ELECTRONIC DATA INTERCHANGE IN DATA SHARING

The most common technology for managing the information flows between larger companies is Electronic Data Interchange (EDI) (Stefansson, 2002). Literature provided different definitions of EDI (Larson & Kulchitsky, 2000):

- *EDI as a medium of transmission* - Monczka & Carter (1988) define EDI as "*the direct electronic transmission, computer-to-computer, of standard business forms between two organizations*." EDI messages can be transmitted in a standard format directly point-to-point or through a third-party network (Monczka & Carter, 1988).
- *EDI as transmission of standardized data* - Walton & Marucheck (1997) define EDI as "*the transmission of standard business documents in a standard format between industrial trading partners from computer application to computer application*." This definition emphasizes the

standard nature of EDI transmissions and distinguishes EDI from e-mail and general Internet access (Walton & Marucheck, 1997).

- *EDI as standard language of electronic business transaction* – Another definition of EDI, available on www.whatis.com, is "*EDI is a standard format for exchanging business data. The standard is ANSI X12*[3]." This definition focuses on EDI as the standard language of electronic business transactions (Sinigaglia, November 2007).

Even though EDI has been a key enabling technology for efficient replenishment and supply chain coordination (Hill & Scudder, 2002), there are several barriers through which smaller companies are not able to pass: the cost of implementing EDI communication technology, and the cost of installation and maintenance of value-added networks (VANs[4]).

Another main problem of EDI is the absence of a prevalent standard: the lack of standardization is causing frustration between many trading partners since they may have to choose between a whole variety of software and technical variations. This problem had led companies to implement EDI facilities only with few selected partners (Larson & Kulchitsky, 2000).

Furthermore, the types of information that EDI can transmit are limited (Pramatari, 2007). In order to cope with this limitation and extend the information exchanged, companies, and in particular the retail sector, have started moving away from EDI to new ways of information exchange, mainly enabled by Internet-based communication platforms and retail exchanges (Sparks & Wagner, 2003).

Other reasons why companies hesitated to join the EDI society are:

- ✓ The investment includes the communication module as far as the information system, turning out to be too expensive;
- ✓ The customers do not require EDI as they don't have that technology;
- ✓ The investment is not economically convenient (the number of transaction is too small) (Stefansson 2002).

As a result of these issues, the adoption of EDI solutions didn't widespread enough, making the limited diffusion of this technology one of the main barriers in benefiting from an implementation of an EDI communication system (Stefansson, 2002).

[3] Standard format developed by Data Interchange Standards Association. Source: www.whatis.com

[4] A value-added network (VAN) is a private network provider (sometimes called a turnkey communications line) that is hired by a company to facilitate electronic data interchange (EDI) or provide other network services. Source: www.whatis.com

4.2 ELECTRONIC DATA INTERCHANGE EVOLUTION: INTERNET-BASED DATA EXCHANGE

The modern widespread of the Internet can contribute and support EDI communications in several ways. Stefansson (2002) identified the 4 main ways in which Internet can help EDI listed below.

- *EDI over Internet*: receive and send EDI messages through the Internet. The negative issue is the approval of acceptance and security issues.
- *EDI over e-mails*: send EDI messages attached to e-mails. The EDI message is enveloped in an e-mail message automatically. This solution guarantees and higher level of security than the previous one, thanks to the security system of the e-mail service.
- *Internet pages*: directly usage of Internet pages for information exchange. These pages can include both static and dynamic information. In addition, the user can consult and modify the selected information.
- *Content mapping*: map the content of an EDI message into a text file or an Internet site. In this way a non-EDI-established partner can access to it. Furthermore, the Internet website can be used just for viewing, printing or direct input.

A sum up of the main differences between EDI and Web-based solutions can be find in Table 2.

		Classical EDI	**Web-based Data Exchange**
Technical elements	Conformation to standards	Companies have to customize EDIFACT[5] standards, understand and control the mapping between internal data end EDI messages.	No use of common standard is required. The intermediate service provider has the responsibility of doing the mapping.
	Use of network infrastructure	VANs are required.	Internet infrastructure is used.
	Software setup	Specialized EDI software is required and mapping and control rules have to be defined for any different message and link.	A web-service client can easily be installed on each computer connected to the web. Companies only define the file input and output directory.
Process elements	Setup time	Set up requires weeks. A test is required for every new link.	Some days. Problems may arise in importing or exporting files.
	Process control and monitoring	The internal IT department has to constantly check the correct functioning of the system.	The monitoring is done by the intermediate service provider that can exploit economies of scale.

[5] EDIFACT (ISO 9735) is the international standard for electronic data interchange (EDI). The term stands for Electronic Data Interchange For Administration, Commerce and Transport.

Cost elements	Setup costs	EDI software requires significant fees.	Setup fee is much lower.
	Cost of network infrastructure	Extra fee has to be paid for the VAN.	Free communication over the Internet.
	On-going cost	Maintenance costs are not negligible.	Fee based on the volumes.

TABLE 2 - CLASSICAL EDI AND WEB-BASED DATA SHARING. *SOURCE: (PRAMATARI, 2007)*

Combining the EDI technology with the Web, the Internet-based data exchange turns out to be reliable, low cost, highly accessible, supportive of high-bandwidth communications, and technically mature, making electronic business affordable even to the smallest companies. This does not mean, though, that there are also structural problems (Larson & Kulchitsky, 2000).

In fact, there are still some valid concerns relating to the use of the Internet for EDI, the main one regards security: although e-mail messages can be encrypted and firewalled, these measures are not yet totally "hacker-proof". This derives from the fact that Internet service provider routes typically involving multiple hops between sender and receiver. Some companies are overcoming this problem by establishing "Extranets[6]" with close trading partners to form a community closed to the wider public. Information is protected by increasingly sophisticated protocol tunneling technology that translates information between protocols and enables users to access only to the sections for which they are authorized (Larson & Kulchitsky, 2000).

Other minor concerns are related to message tracking, audit trails and authentication.

4.3 SELECTION OF THE BEST SOLUTION

Apart from the different technology solutions available in the market, a general collaboration con be identified referring to 2 dimensions: *process complexity* and *information intensity*. Combining these 2 dimensions, the depth of the collaboration can be defined (Figure 6). Pramatary (2007) defined 2 main preferred solutions according to the depth of the collaboration.

- *Centralized web-platform* – this solution is suitable for low information intensity and low process complexity. If a log-in system is included in the platform, this solution can turn out to be suitable also for and higher information intensity, with an higher number of people involved. The problem of this solution is that many people can access to the same platform, modify it simultaneously and lead to a non-acceptance response by the system.

[6] An Extranet constitutes a private business network of several cooperating organizations, typically trading partners, customers and suppliers who form a strong communication bond. Source: (Larson & Kulchitsky, 2000).

- *Decentralized solution* – this configuration is more suitable for processes with high complexity. The backbone of this system is the decentralization and duplication of minor systems that are accessible by the different actors. Then, these individual systems can automatically communicate with the central back-office, managing the overlapping of information. The main problem of this application is the need of a standard along all the actors (Pramatari, 2007).

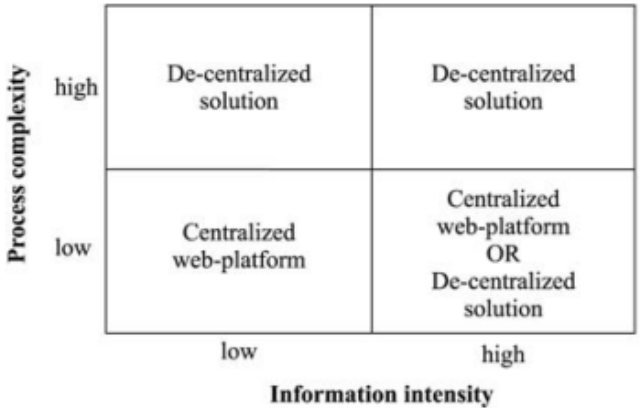


FIGURE 6 - DEPTH OF THE COLLABORATION AND SOLUTION TYPE. *SOURCE: (PRAMATARI, 2007)*

5. CONCLUSIONS

SCM is not a new concept: scholars have spent a lot of work on that issue and all the companies are more or less familiar with it, even though Christopher & Holweg (2011) suggested that, given the recent changes in the world market, the traditional SCM concept needs a revision.

While the reasons for a SCM project are shared among most of the companies (reduce costs, have a lighter company, get access to worldwide resources and improve service level), there are different practices that companies follow towards SCM: from a simple an application of information technology solutions, to a practice to manage closer relationships, finishing with a cultural orientation or philosophy that guides decision making. As a consequence of these views, different integration levels can be identified: from the simple integration of internal processes, to a complete integration with suppliers' suppliers and client's clients.

A fundamental role in the integration sharing is information sharing. An important channel for information sharing is EDI technology, and in particular the most recent Web EDI, that was created to face the high investments needed to implement and EDI solution.

With a strong orientation towards integration and the usage of innovative web-based solutions, companies can integrate their operations with suppliers and customers, in order to reduce costs and gain competitive advantages.

B. LITERATURE REVIEW

In this section the analysis of the modern literature will be performed. The development of the research will follow two main topics:

1. *The Supplier Selection problem – This chapter will analyze the supplier selection problem and will cover the analysis of the literature on supplier selection, with an overview of the initial researches (from 1966 to 2006) and with a deep attention of the most recent ones (from 2007 to 2012). The purpose of this section is to analyze two different issues:*
   a. *Supplier selection indexes –analyze the research works performed by scholars in order to identify the indexes used for the selection. The scope of this part is to define the most used ones to be used for my specific model.*
   b. *Supplier selection models –explain the most used models to combine the different indexes identified in the previous point, highlighting the strengths and weaknesses of each model, in order to define the best one to be used for my research.*

2. *E-invoicing and Dematerialization – This second topic will deepen the concept of invoicing, e-invoicing and dematerialization. The different adoption paradigms, the legal framework and the benefits achievable are analyzed too. Further attention will be paid on the analysis of the supply market and the barriers of adoption.*

B.1 SUPPLIER SELECTION

1. INTRODUCTION AND FRAMEWORK

"The vendor selection problem (VSP) is associated with deciding how one vendor should be selected from a number of potential alternatives" (Dickson, 1966; Weber, et al., 1998). Supplier selection is a fundamental activity as it influences company's performance on costs, quality, delivery and service along the whole supply chain: the selection of the correct supplier can reduce purchasing costs and improve competitiveness, while the wrong choice can upset the company's financial and operational position (Faez, 2009; Amid, et al., 2006).

Due to the increased level of openness to global competition, companies are under pressure to rationalize their expenses and reduce their costs. On average, manufacturers' purchases of goods and services constitute up to 70% of the production cost, percentage that increases up to 80% in case of high technology firms (Ghobadian, 1993). The selection of the appropriate supplier is a fundamental step for this cost reduction (Dahel, 2003; Chamodrakas, et al., 2010).

Moreover, modern production systems require a high precision on the outsourcing both in terms of expected quantity and quality. If it is considered that many businesses outsource their operations in order to utilize more efficiently worldwide resources, it is understandable why decision makers are so worried about the effectiveness and rationality of the supplier selection process (Yang & Chen, 2006; Chamodrakas, et al., 2010).

On the other hand, pressure derives also from the consumer side: today's consumers are demanding cheaper and higher quality products, on-time deliveries and excellent after-sale services (Sonmez & Mahmut, 2006).

The VSP looks already complicated in theory, but in practice, vagueness and imprecision of the goals, constrains and parameters, makes the decision-making even worst (Amid, et al., 2006).

Several literature studies have been conducted during last years to identify the best variables to be considered within the potential suppliers' evaluation and the proper mathematical models to be applied for assigning the correct weight to each criteria; it became evident though, that there are no common factors to solve the supplier selection problem (Chamodrakas, et al., 2010).

Furthermore, the literature does not follow a common path, but is characterized by several independent works that try to identify the best decision criteria and evaluation models depending on the industry.

Sonmez & Mahmut (2006), after having reviewed 147 papers, have identified that the main attention of the scholars was related to:

- decision criteria and associated weightings used for supplier selection, and
- decision making methods/tools used and/or proposed for supplier selection.

It was also observed that, from the 1990s on, there was a more recent trend towards studying the effects of buyer-seller relationships, international supplier selection and online selection of suppliers. According to Sonmez & Mahmut (2006), these phenomena can be bounded up with globalization and rapid development of information technology. It was underlined, though, that there were a lack of attention towards safety and security issues; furthermore there were hardly any paper dealing with the supplier selection for services (Sonmez & Mahmut, 2006).

In order to present the analysis in a clearer way, this chapter will be divided in 4 parts.

1. *Supplier selection problem* - The first part is dedicated to the supplier selection problem, with the definition of the problem, the description of the main phases, the different purchasing situations, and the factors that affects the identification of the selection criteria.
2. *History of supplier selection problem* - Then following one is the analysis of the history of supplier selection researches, with a screening of the most used indexes. This part will cover the literature from the beginning (1966) to 2006. The reason for this year-choice is that in 2006 we have different complete literature reviews (Amid, et al., 2006; Sonmez & Mahmut, 2006; Marasco, 2007) published in relevant journals that can provide a comprehensive overview on the subject. This section will also include a small parenthesis on supplier selection problem applied to the outsourcing of logistics activities.
3. *Selection models* - This part includes an overview of the most common selection methods used in the literature, with a brief presentation of the minor ones, and a deeper analysis of the most frequently used. This section is useful, first, to have a general idea of the methodologies actually available on the market, second to have a guideline through the analysis of the modern works (these works will be divided according also to the selection method adopted).
4. *Modern works on supplier selection* - The last part is a more detailed analysis of the most recent papers, going through each single work and with an increased focus on the sectors involved and the methodologies utilized.

2. SUPPLIER SELECTION PROBLEM

2.1 DEFINITION OF SUPPLIER SELECTION PROBLEM

> SUPPLIER SELECTION AND EVALUATION IS THE PROCESS OF FINDING THE SUPPLIER BEING ABLE TO PROVIDE THE BUYER WITH THE RIGHT QUANTITY AND/OR SERVICES AT THE RIGHT PRICE, AT THE RIGHT QUANTITIES AND THE RIGHT TIME (SONMEZ & MAHMUT, 2006; SARKIS & TALLURI, 2002).

Supplier selection is a multiple criteria decision-making (MCDM) problem which is affected by several conflicting factors (Amid, et al., 2006).

Ghodypour and O'Brien argued that there are 2 types of supplier selection problem: *single sourcing* and *multiple sourcing*. In the first type, it is assumed that each supplier can satisfy the buyer's entire requirements in terms of demand, quality and delivery. In this case, the management of the buyer needs to make only one decision: which supplier is the best? Multiple sourcing problems, on the other hand, assume that there are some limitations in supplier's capabilities to satisfy the buyer. In this configuration the buyer has to purchase some parts from one supplier and other parts from another one.

It is also a common usage to rely on multiple sourcing, even though one supplier could satisfy the whole demand, for screening superior deals. Under multiple sourcing circumstances, the management of the buyer needs to make two types of decisions: 1) which suppliers should be used, 2) what is the order quantity of a part allocated to each of the selected suppliers? (Ghodsypour, 2001; Ting & Cho, 2008).

De Boer (2001) defined this selection process consisting of four stages:

1. identification of the need for a new supplier;
2. identification and elaboration of selection criteria;
3. initial screening of potential suppliers from a large set;
4. final supplier selection (de Boer, et al., 2001).

And later on, Chamodrakas (2010) added a fifth point:

5. continuous evaluation and assessment of selected suppliers (Chamodrakas, et al., 2010).

De Boer (2001) work was not limited to the simple definition of the four stages within the supplier selection process, but he identified the main characteristics depending on the type of product involved. To do this De Boer (2001) used two previous classifications presented marketing literature:

Kraljic's (1983) purchasing portfolio and Faris' (1967) purchasing situations (Faris, 1967; Kraljic, 1983).

The two models can be seen in Table 3 and Table 4.

Purchasing situation	Characteristics
New task situation	Entirely new product/service; No (known) suppliers; High level of uncertainty; Extensive problem solving.
Modified re-buy	New product/service to be purchased from a known supplier; Existing (modified) product to be purchased from new supplier; Moderate level of uncertainty; Less extensive problem solving.
Straight re-buy	Perfect information concerning specification and supplier; Involves placing and ordering within existing contracts and agreements.

TABLE 3 - CLASSIFICATION OF PURCHASING SITUATIONS. *SOURCE: (FARIS, 1967)*

	Low-supply risk	**High-supply risk**
Low-profit impact	*Non critical items* Many suppliers, rationalized purchasing and procedures; systems contracting and automation/delegation	*Bottleneck items* Monopolistic supply market and long-term contacts. Develop alternatives and contingency planning.
High-profit impact	*Leverage items* Many suppliers available with competitive bidding. Short term contracts and active sourcing.	*Strategic items* Few and difficult suppliers with medium/long-term contracts. Supplier development/partnership and continuous review.

TABLE 4 - PURCHASING PORTFOLIO MATRIX. *SOURCE: (KRALJIC, 1983)*

In Kralljic's (1983) work, the perceived importance and complexity of the purchasing situation is identified in terms of two factors: *profit* and *supply risk*. Profit impact includes such elements as the expected monetary volume involved with the goods and/or services to be purchase and the impact on future product quality. Indicators of supply risk may include the availability of the goods/services under consideration and the number of potential suppliers (de Boer, et al., 2001).

Going back to de Boer's (2001) framework, a first distinction was made between one-off and/or first-time supplier selection versus repeated supplier selection. This distinction follows very closely Faris' (1967) distinction between new task and re-buy.

In crossing Kraljic's (1983) and Faris' (1967) frameworks, de Boer, et al. (2001) made the following considerations.

- For new task situations there were no need to distinguish between situations with relative high or low importance as the purchasing approach would be the same. As the purchase deals with new items, no historical data are available and the process has to be done step by step from the beginning;
- For straight re-buy the situation has to be distinguished. In case of *non-critical item*, because of the low value of the product, it's probable that there is no frequent research for suppliers and usually a set of related routine items are associated to one or two suppliers to achieve a highly efficient ordering. In case of *bottleneck* and *strategic items*, the choice of the supplier is also more or less fixed. Small changes in the specifications of the items are automatically dealt with by the existing supplier. However, the reason for this is very different from routine items: with a high supply risk, there are virtually no suppliers to choose from immediately because the choice set is often much smaller. Decision models are primarily used as means for periodic evaluation of the existing supplier.
- For modified re-buy situations *leverage items* are typically involved: there are many suppliers to choose from while the high value (and saving potential) of the items justifies proactive search of frequent selection of suppliers. However, the execution of the first steps in the process (problem definition, formulation of the criteria and prequalification), is often decoupled from the final choice.

Back to the selection process defined by De Boer (2001), the initial screening and the final supplier selection involves two main tasks, which are also central to any decision making problem:

- ✓ the process of evaluation and assessment of each single supplier, and
- ✓ the aggregation of evaluations and assessments to make a choice and select the best one.

As can be seen in the following graph, step 3 and 4 of the process can be seen as a smaller process: first the attributes against which the potential suppliers will be evaluated have to be defined (Identifying attributes). Then, for each attribute, scales and metrics are determined. In order to give a rating to the each supplier, a further step is necessary: each criterion has to receive a weight to indicate the relative importance and contribution to the general goal. Note that each criterion (father criteria) can be divided into sub attributes (child attributes), in this case each child attribute has to receive a weight in accordance to the importance and contribution to the father attribute.
Finally, the set of indexes has to be populated with suppliers' data, and, once each candidate supplier has received its score, it is necessary to aggregate these scores and ratings. As these values can be both qualitative and quantitative, it is paramount to have a sound and rational logic to perform the comparison (Sonmez & Mahmut, 2006).

The literature has identified two main approaches for aggregating scores/rating:

- compensatory (linear), or
- non-compensatory (non-linear) (Da Silva, et al., 2002; Patton, 1996).

If compensatory approach is selected, a weak performance in one criterion is offset by a good performance on other criteria. On the other hand, with a non-compensatory model, weaknesses in criteria are not compensated with strength in others (Sonmez & Mahmut, 2006).

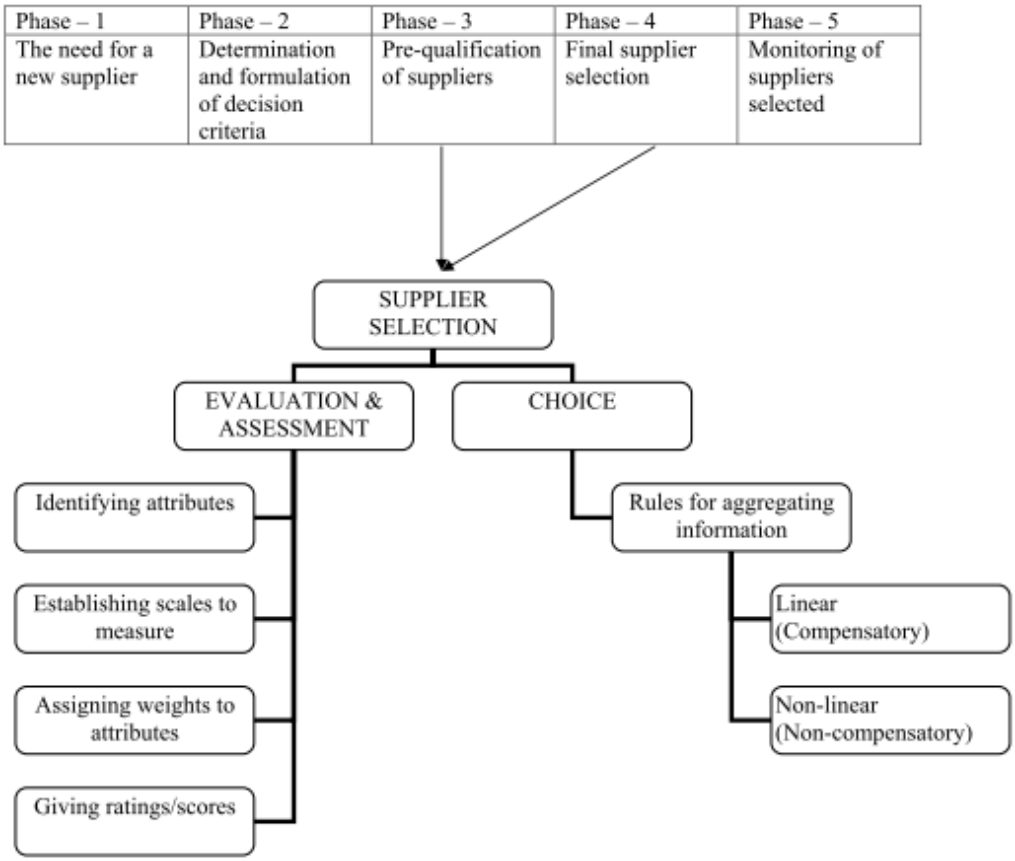


FIGURE 7 - PHASES OF SUPPLIER SELECTION PROCESS AND TASKS IN SUPPLIER SELECTION. *SOURCE: (SONMEZ & MAHMUT, 2006)*

.2 FACTORS AFFECTING SELECTION CRITERIA

As can be easily noticed, the process requires the identification and elaboration of decision criteria (step 2); this process changes from organization to organization and from contest to contest: "*different organizations may choose different decision criteria for supplier selection according to several factors, the most important one being the size of the buyer organization*" (Pearson & Ellram, 1995).

There are several factors that, in addition to the size, influence the selection of the criteria. First of all the sourcing strategy plays an important role, identifying the number of suppliers and the minimum order quantity to be purchased; secondly comes the product type. Lehman & O'Shaughnessy (1982) defined the following possible product types and the specific most relevant criteria.

- *Routine order products*: products with no problems related to functional capabilities or learning to use. In this case *reliable delivery* and *price* were defined as the most important criteria.
- *Procedural problem products*: products for which there is no functional problems, but there could be some with the learning to use the product. *Service* and *delivery* are the most important criteria.
- *Performance problem products*: for these products there is the possibility that the performances are not satisfactory. The most important criteria are: *delivery* and *service*.
- *Political problem products*: those products which require large capital outlays and multiple decision makers. *Price, reputation,* and *product reliability* were identified as the most relevant criteria (Lehmann & O'Shaughnessy, 1982; Wilson, 1994).

The manufacturing strategy affects the supplier selection process too: make-to-order (MTO), make-from-stock (MFS), and make-to-stock (MTS) policies can influence the decision maker (Cakravastia, et al., 2002). The last two factors are the preference of the buyer towards the location of the supplier and the number of people (single or department) in head of the decision process.

It is generally agreed in the literature that the following issues make the supplier selection decision making process difficult and/or complicated (Sonmez & Mahmut, 2006):

- ✓ *multiple criteria* – Both qualitative and quantitative;
- ✓ *conflicts among criteria* – conflicting objectives of the criteria;
- ✓ *involvement of many alternatives* – due to fierce competition;

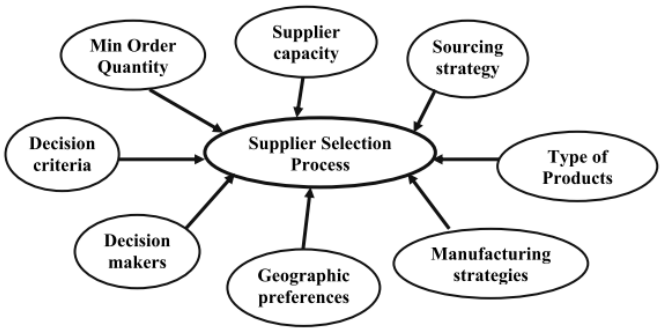


FIGURE 8 - FACTORS AFFECTING SUPPLIER SELECTION CRITERIA. SOURCE: *SONMEZ & MAHMUT, 2006*

- ✓ *internal and external constrains* imposed on the buying process.

3. HISTORY OF SUPPLIER SELECTION PROBLEM

3.1 METHODOLOGY

In these following paragraphs I will present the analysis of the history of the supplier selection problem (from 1966 to 2006 included). In order to better tackle this research, a further distinction was made:

- First the works related to the supplier selection in a general ways are presented ("general" means that they are not referred to any particular industry or product).
- Then, the focus is moved to the specific works ("specific" means that they are referred to a particular industry or product) classified according to the main topics. In this section, a specific attention is put on the 3PL selection problem, and, to do so, a small parenthesis on supplier selection for the outsourcing of logistics activities is present.

3.2 GENERAL VIEW

The first example of supplier selection and evaluation study is dated back to 1966, when Dickson analyzed a questionnaire sent to 273 purchasing agents and identified 23 different common criteria. Quality, delivery, performance history, warranties and claim policies, production facilities and capacity, price and technical capabilities were the most important ones (Dickson, 1966). In Table 5 these 23 criteria are represented with the order of importance.

Pan (1989) proposed multiple sourcing in supplier selection decision in order to improve the reliability of supply for critical materials. Considering that most purchasing managers agreed that buying from more than one source will reduce the risks of shortages or stock outs, Pan formulated a single objective linear programming model to find the best supplier based on 3 decision criteria: price, quality and service. In this model the total cost was minimized subject to the given level of quality and service constrains (Pan, 1989). Ellram (1990) tried to give more attention to the supplier selection in case of potential partnerships involved. She applied a hierarchy framework that, in addition to the standard criteria, such as cost, quality, delivery reliability and other similar factors, included innovative relationship-based indicators. The result was a set of indicators divided into 4 main categories (Ellram, 1990):

1. *financial issues* – Economic performance and financial stability;
2. *organizational culture and strategy issues* – Feeling of trust; management attitude for the future; strategic fit; top management compatibility; compatibility across levels and functions of buyer and supplier firm; and supplier's organizational structure and personnel;

3. *technological issues* – Assessment of current manufacturing facilities; assessment of future manufacturing capabilities; supplier's design capabilities; supplier's speed in development;
4. and *other factors* – Safety record of the supplier; business references and supplier's customer base.

Weber in 1991 reviewed 74 articles discussing supplier selection criteria and confuted Dickson's studies, showing that *net price* was the most important one, followed by delivery, quality, facilities and capacity, geographical location, and technology capability; furthermore, Weber tried to identify the most important criteria for a Just In Time (JIT) system. The results of the confutation and of the application to a JIT system can be seen in Table 5.

Criteria	Dickson 1966		Weber 1991	
	Rating	Rank*	Normal rank	JIT rank
Net price	6	2	1	3
Delivery	2	1	2	2
Quantity	1	1	3	1
Production facilities and capacity	5	2	4	5
Geographical location	20	3	5	4
Technical capability	7	2	6	6
Management and organization	13	2	7	8
Reputation and position in industry	11	2	8	
Financial position	8	2	9	
Performance history	3	1	10	
Repair service	15	3	11	11
Attitude	16	3	12	7
Packaging ability	18	3	13	9
Operating controls	14	2	14	10
Training aids	22	3	15	
Bidding procedural compliance	9	2	16	
Labor relations records	19	3	17	
Communication system	10	2	18	
Reciprocal arrangements	23	4	19	
Impression	17	3	20	
Desire for business	12	2	21	
Amount of past business	21	3	22	
Warranties and claims	4	1	23	
* 1= Extreme importance, 2= Considerable importance, 3= Average importance, 4= Slight importance				

TABLE 5 - DICKSON'S AND WEBER'S CRITERIA. *SOURCES: (DICKSON, 1966; WEBER, 1991)*

Finally, in Weber's research, it was also underlined the fact that supplier selection criteria is a multi-criteria problem and the priority of criteria depends on each purchasing situation (Weber, 1991).

The models presented up to now, provided some common and shared criteria. A comparison of these criteria can be seen in the Annexes. From this comparison some common points can be derived: price, quality and technical capability are shared by four authors up to five. Other important

dimensions are related to financial performances and reputation of the supplier (three up to five authors).

Ghodsypour and O'Brien (1998) analyzed the supplier selection problem considering different levels of integration between the actors. In their study, Ghodsypour and O'Brien defined 5 different levels of integration and the relative selection factors. The results of can be seen Table 6 (Ghodsypour & O'Brien, 1998).

Level	Description	Selection criteria
1	No integration assumed.	Price and quality
2	Logistics integration exists between buyer and supplier. The supplier has an important role in the buyer's competitiveness. For this reason great importance is given to suppliers' logistical performance.	Quality and price. Operational logistics elements: reliability, flexibility, supply lots, and lead time.
3	Operational integration between buyer and supplier. Usually this level is selected for Just In Time (JIT) or Total Quality Management (TQM). Therefore not only the output characteristics of the supplier should be considered, but the way in which these services are provided should also be taken into account.	Process capability: set up time, lot size, lead time. Quality: defect rate (should be the same between the two actors).
4	Process and products are integrated between the two actors.	Quality, price, process capability. Human resource: design involvement, management ability and culture.
5	Business Partnership.	All the criteria of the other levels plus a further attention on supplier's strategic directions and technological dimensions.

TABLE 6 - SELECTION CRITERIA ACCORDING TO THE INTEGRATION LEVEL. *SOURCE: (GHODSYPOUR & O'BRIEN, 1998)*

Muralidharan, Anatharaman, and Deshmuck (2002) tried to develop a model to guarantee and facilitate consensus among the decision makers combining group members' preferences into the ranking. The result was to identify the following attributes: quality, delivery, price, technical capability, financial position, past performance attitude, facility, flexibility and service. Each attribute was then specified in lower levels. (Muralidharan, et al., 2002) The detailed explanation of each attribute can be seen in the Annexes.

Humphreysa, Wong and Chan (2003) realized that environmental pressure was increasing leading to a higher attention to environmental issues in the supplier selection process. For this reason Humphreysa et all. integrated environmental criteria into the supplier selection process (Humphreys, 2003). The model proposed included both quantitative criteria, used to identify environmental costs, such as pollutant effect and improvement, and qualitative criteria such as management competencies, green image, design for environment, environmental management systems, and

environmental competences. Each of these categories has been divided then into several sub criteria. The whole model can be seen in Figure 9.

Finally, Yang & Chen (2006) performed a literature review and an interview with three business executives that concluded to six qualitative criteria including (in order of importance) quality, cost, delivery, design & technical capability, production capacity, IT system, customer service, distance, turnover and finance (Yang & Chen, 2006).

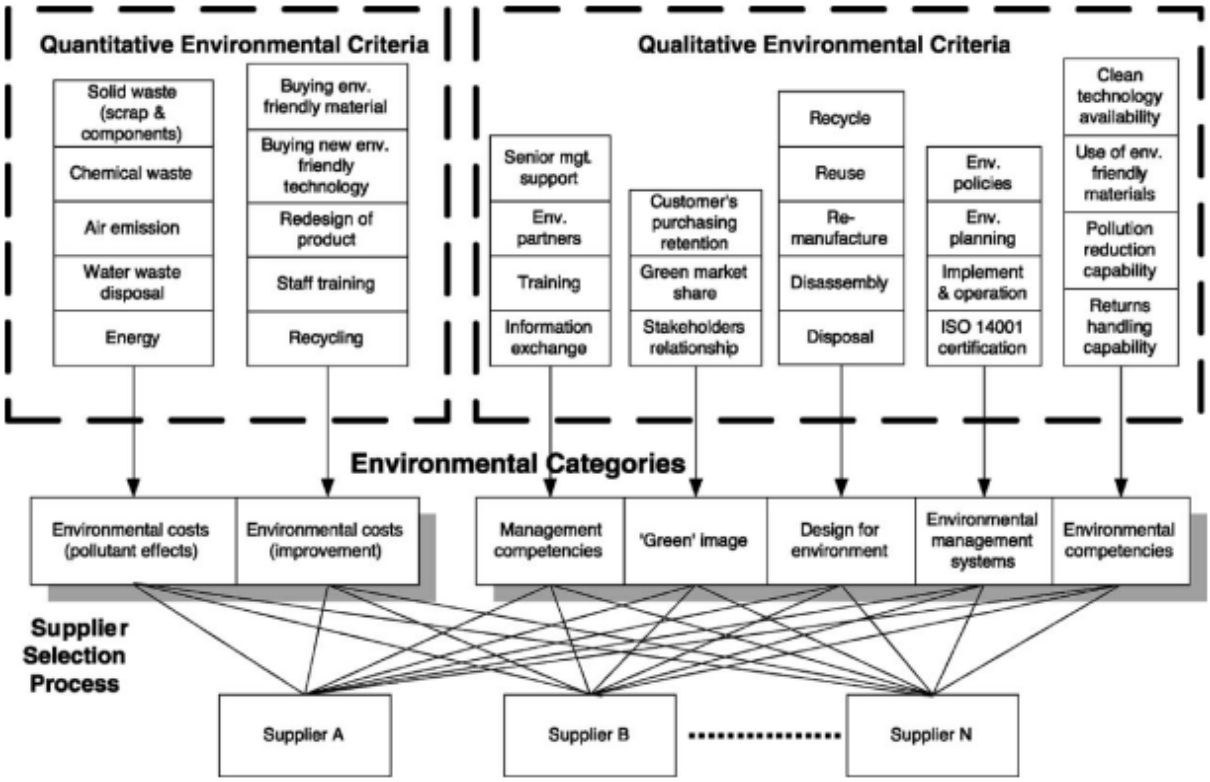


FIGURE 9 - ENVIRONMENTAL CRITERIA MODEL. *SOURCE: (HUMPHREYS, ET AL., 2003)*

3.3 SPECIFIC VIEW

In this section I will, referring to literature, summarize the specific studies related to some particular sectors and written before 2006.

Previous researches are not equally distributed among the industries, in fact Amin and Razmin (2009) underlined that the majority of the publications have been written in the context of selecting a supplier for the purchase of products to be used in a manufacturing environment, and little attention was given to the service industry (Amin & Razmi, 2009). The major difference between parts and services purchasing is that the services cannot be “stored” and so there are no inventory costs associated with service purchasing (de Boer, et al., 2001; Aissaoui, et al., 2007).

- Choi and Hartley (1996) analyzed the auto industry of the United States considering the whole supply chain, and trying to highlight any differences between direct/indirect suppliers and the auto assemblers. The result was to identify 24 criteria, classified in 8 predominant factors guiding supplier selection: consistency (quality and delivery), relationship, flexibility, customer service, reliability, price, financial issues and technological capability. While the first six factors were commonly shared by suppliers and auto manufactures, the last two (financial issues and technological capability), were found important only for car manufacturers (Choi & Hartley, 1996).
- Degraeve & Roodhooft (2000) proposed an effective methodology based on Activity Based Costing for a printing company (Degraeve & Roodhooft, 2000);
- Oliveira & Lourenco (2002) discussed the problem of selecting suppliers for the constitution of pipeline networks for a gas distribution company. They developed a multi-source and multi-period model that allocated construction orders to a pool o pre-qualified set of suppliers (Oliveira & Lourenço, 2002);
- Degraeve, et al. (2004) used the concept of total cost of ownership to select airlines for a major company. They developed a large complex mixed integer program that accounts for several airline fare discounting scheme (Degraeve, et al., 2004);
- Klundert, Kuipers, Spieksma, and Winkels (2005) reported on a model for selecting international communication carriers for a major telecommunication service provider. They accounted for volume discounts and showed that a special case of their model results in a min-cost flow model (Klundert, 2005).

3.4 OUTSOURCING OF LOGISTICS ACTIVITIES

The outsourcing of logistics activities to third-party logistics service provider (3PL), has become a common practice in the last decades. Given this trend, and the relevance of these activities in a company's performance, the literature has spent great efforts in analyzing this issue.

Before explaining the works related to 3PL selection, a brief overview on supplier selection problem for logistics activities is needed.

3.4.1 SUPPLIER SELECTION PROBLEM FOR LOGISTICS ACTIVITIES

Different researches stated that the commonly known drivers for outsourcing are: need of the organizations to concentrate on core competences, cost reduction, development of supply chain partnership, restructuring of the company, success of the firms using contract logistics, globalization and new markets, improvement of services, operational flexibility, avoid investments and efficient operations (Hertz & Alfredsson, 2003; Wilding & Juriado, 2004). Among these, one of the most

important reason for outsourcing is the capabilities of the providers to support their clients with the expertise and experience that otherwise would be difficult to acquire or costly to have in-house (Jharkharia, 2007).

Even though there are several selection processes and methods proposed in the literature, among all Andersson and Norrman's eight-steps plan - this process can be seen in Figure 10 - (Andersson & Norrman, 2002), a well-defined comprehensive methodology that systematically incorporates all the relevant criteria in logistics outsourcing is still awaited (Jharkharia, 2007).

More recently, Jharkharia and Shankar (2007) analyzed all these models and proposed a methodology for the initial screening of the providers. Their model is based on a nine-step process that begins with the definition of a team of competitive managers, the service and distribution objectives, and the distribution and functional specifications. Goes through the selection of potential suppliers to which a Request for Information (RFI) and an eventual Request for Proposal (RFP) is sent. And finally, after the evaluation of the requests, the field visit and inspection are made, and the final decision is taken. The signed contract should include: scope of the work, damages, individual status, responsibilities, risks and rewards, remedies, extra services, termination, agreement modification, liabilities, limitations, compensation, insurance, rate adjustments, service compensations, and performance measurement issues (Jharkharia, 2007).

The following figure shows the comparison between the two models: Andersson & Norrman's and Jharkharia & Shankar's.

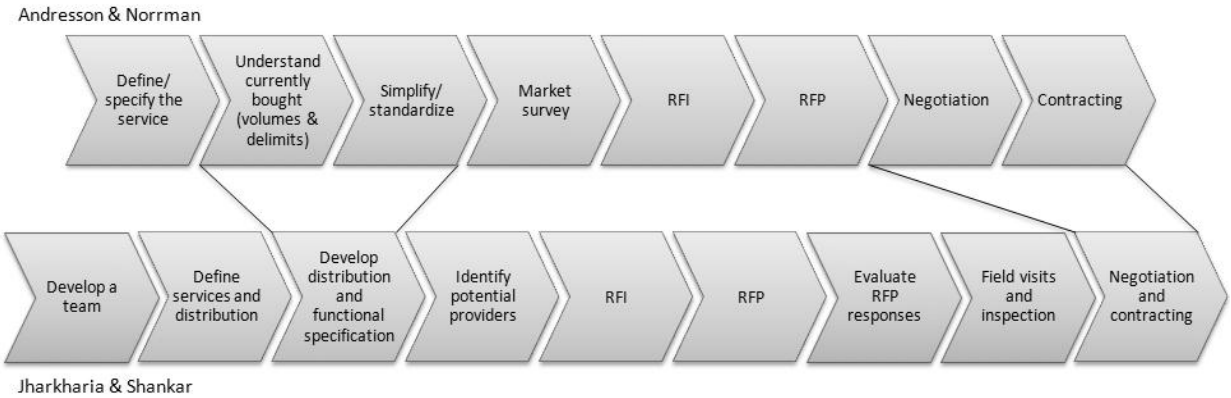


FIGURE 10 - COMPARISON BETWEEN ANDERSSON AND JHARKHARIA MODELS. *SOURCES: (ANDERSSON & NORRMAN, 2002; JHARKHARIA, 2007)*

A further contribution is the identification of the problems (listed below) that are commonly encountered by users in the selection of a provider (Jharkharia, 2007; Andersson & Norrman, 2002).

1. *Lack of knowledge* – A company willing to outsource its logistics activities may not have enough people with in-depth knowledge of outsourcing related issues. Therefore the formation of a group of experts to select a provider is also sometimes a tough task.
2. *Lack of information* – The users rarely have complete information about the prospective providers, for that reason they have to base their evaluations on the information received and declared by the providers themselves. This information may not always be true.
3. *Comparability of the proposals* – The request for proposal (RFP) received by the candidates may suggest different solutions and, though, be difficult to compare.
4. *Not clear needs* – Expectations of the user and promises made by the providers are often unrealistic. Some users are not really in a position to define their actual logistics requirements.
5. *Subjective criteria* – In the evaluation, there are different subjective criteria, such as reputation and satisfaction levels that are difficult to quantify and compare. How to compare various providers on many different criteria is another problem.
6. *Long terms* – After considering all the relevant points, the selection process may run over months.

3.4.2 3PL SELECTION CRITERIA

As stated previously, the supplier selection problem in third part logistics providers has covered a great part of the researchers: many studies tried to define how to calculate the performances of 3PL services and provide a complete and reliable model to evaluate potential suppliers.

McGinnis in 1995 and Ghodsypour performed and empirical study in the US, questioning 163 logistics services users and depicted that both firm's competitive responsiveness strategy and level of environmental hostility was affecting the selection criteria; in addition, McGinnis also showed that there are 8 important criteria which are: on time shipment and deliveries, superior error rates, financial stability, creative management, ability to deliver as promised, availability of top management, responsiveness to unforeseen occurrences, and importance of meeting performance requirements before price discussion occurs (McGinnis, et al., 1995).

Woo and Ennew (2004) mentioned that there are 6 dimensions to be considered in business-to-business professional services: cooperation, service quality, customer satisfaction, behavioral intention, adaption and atmosphere (Woo & Ennew, 2004). In the same year, Wilding and Juriado suggested that performances of 3PL companies can be measured by these clusters: delivery timeliness, cost, overall quality, inventory management, picking accuracy, responsiveness and

flexibility, error and damage assessment, lead-time, receiving/unloading and dispatch/loading, documentation, variation in actual and expected performance and others (Wilding & Juriado, 2004).

Two different studies have been done in 2004 regarding warehouse-outsourcing selection. The first one was performed by Colson and Dorigo; they presented a software tool which allows the selection of public warehouses based on: storage surface and volume, dangerous items, geographical distance to highway connection, certification, assistance with customs, use of technology such as RFID/Bar-coding, and modem connection (Colson & Dorigo, 2004). The second is attributable to Moberg and Speh (2004); their empirical survey in the US showed that the most important indicators for choosing a particular 3PL are related to responding to service requests, quality of management, and track record of ethical performance. The three least important criteria are investment in state-of-the-art technologies, size of the firm and national market coverage (Moberg & Speh, 2004). (Aguezzoul, 2007)

Bottani and Rizzi (2006) presented a multi-attribute approach to select and rank the most suitable 3PL service providers. They applied service criteria such as breath of service, business experience, characterization of the service, compatibility, financial stability, flexibility of service, performance, price, physical equipment and information, quality, strategic attitude, trust and fairness (Bottani & Rizzi, 2006).

In 2007, Aguezzoul performed a literature review on 3PL selection. In his study, Aguezzoul quoted a research made by the International Warehouse Logistics Association (IWLA)[7] that showed the major changes in the selection criteria's rankings. The study is summarized in the Annexes. In 1994 and 1999, the top three determinants in selecting a 3PL were service quality, reliability and on-time performance. By 2003, the price became the most important selection criteria. This change is mainly due to the increase of quality and number of services offered by 3PL. While the cost of these services continued to decrease, it remained the crucial part of the negotiation with the 3PL (Aguezzoul, 2007).

3.5 CONCLUSIONS

To conclude, it can be noticed that the pre 2006 works are mostly related to the selection of suppliers for material purchasing, with fewer attention on service providers and mostly limited to 3PL selection. The oldest works, the ones before 1996, are mainly referring to the 23 indexes define by Dickson (1966). On the other hand, more recent works tried to reorganize in different ways and clusters the Dickson's criteria, defining new and innovative ones, such as environmental savings and human resources policies.

[7] International Warehouse Logistics Association comprises more than 550 logistics companies of North America. www.iwla.com

A particular attention was spent on 3PL selection criteria, a common path that can be identified is that, at the beginning of the diffusion of 3PL services the attention was concentrated on performance indexes (such as on time delivery and service quality), while, when these services becomes more mature, the attention was moved towards costs and experience.

4. SELECTION MODELS

With reference to the models showed by de Boer (2001) and Chamodrakas (2010), step 3 and 4 require the prequalification and the final choice of the supplier. To make this decision, matematical models to compare different selection criteria are required. In this paragraph I will provide an overview of the main evaluation model proposed and used in the literature.

Several selection techniques has been used during previous work: analytic hierarchy process (AHP), multi-objective programming (MOP), expert systems, data envelopment analysis (DEA), mixed integer programming (MIP), goal programming (GP), mathematical programming (MP), linear weighting (LW), total cost of ownership (TCO), genetic algorithm (GA), analytic network process (ANP), case-based reasoning (CBR), data mining (DM), cluster analysis (CA), activity based costing (ABC), technique for order preference by similarity to the ideal solution (TOPSIS), rough sets theory (RST), grey approach, artificial neural network (ANN), and quality function development (QFD) (Amin & Razmi, 2009).

In addition to these methods, several other examples of combinations and application of fuzzy theories have been used.

4.1 SELECTION MODELS CLASSIFICATION

As it happened with supplier selection criteria, there is no common classification of the evaluation models: different authors tried to classify these models according to different drivers.

In the following paragraph I will try to combine 4 different frameworks derived from 4 different works: de Boer (2001), Yang and Chen (2006), Sonmez (2006) and Aguezzoul (2007). These researches present basically the same classification, even if, sometimes, they use different names.

The categories identified, and the comparison between them, can be seen in Table 7.

<table>
<tr><th>Sonmez (2006)</th><th>Aguezzoul (2007)</th><th>De Boer (2001)</th><th>Yang and Chen (2006)</th></tr>
<tr><td>Multi Criteria Decision Making (MCDM)</td><td colspan="3">Linear weighting models</td></tr>
<tr><td colspan="3">Artificial intelligence & Expert systems</td><td></td></tr>
<tr><td>Multivariate statistical</td><td colspan="2">Statistical/probabilistic approaches</td><td></td></tr>
</table>

analysis			
Mathematical programming	Mathematical programming		
	Total cost based approaches		
Other decision making			

TABLE 7 - COMPARISON BETWEEN CLASSIFICATION FRAMEWORKS. *SOURCE: (SONMEZ & MAHMUT, 2006; AGUEZZOUL, 2007; YANG & CHEN, 2006; DE BOER, ET AL., 2001)*

MCDM/Linear weighting models – these are the most utilized in previous works. The core of these models is to place a weight on each criterion (the biggest weights indicates the highest importance) and provide a total score for each supplier by summing up the performances on the criteria multiplied by the associated weights. The factors can be equally weighted (easy to apply but with scarce reflection in reality) or a model can be used to assign different weights. In addition to that, we can distinguish between:

- *Compensatory models*: a high ranting in one criterion can compensate a low rating on another;
- *Non compensatory models*: a minimum level on each criterion is required.
- *Quasi-compensatory* models: tradeoff between the previous two. This model allows setting some predefined limits to the compensation effect. Outranking is an example.

Other examples of these methods are: Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP).

Artificial intelligence & Expert Systems – The aim of these methods is to integrate qualitative factors and human expertise in the selection process. Artificial intelligence models are based on computer-aided systems that can be trained by a purchasing expert or historical data. In particular, the expert system model suggests how to include in the process the knowledge derived from the experts' evaluations as well as the information collected from literature. The two main models related two this category are: Case-Based Reasoning (CBR) and Neural Networks.

Multivariate Statistical/probabilistic approaches – the models belonging to this category are mostly related to statistical tools and they deal with stochastic uncertainty related to the vendor choice. The most important are standard deviation and mean, followed by some more refined tools such as structural equation modeling and factor analysis.

Mathematical programming – these models consist of a function objective to be optimized and a set of constraints faced by the decision-maker. The models are used to formulate supplier selection problem in terms of an objective function to be maximize or minimized. Examples of this category are linear and non-linear programming models

Total cost based approaches – these models attempt to include the quantifiable costs that are incurred throughout the purchased item life cycle into the supplier selection model. Total cost based methods basically try to summarize and calculate all the costs associated with the choice of vendors and subsequently adjust or penalize the unit price proposed by the supplier.

Other decision makes tools – This category is shared only by Sonmez & Mahmut (2006) and it includes the methods adopted to face a multi-decision maker problem. In fact Sonmez & Mahmut state that, as the supplier selection process is becoming more and more strategic, the decisions to be taken are not delegated to only one person, but have to be shared and taken by different actors (Sonmez & Mahmut, 2006; Aguezzoul, 2007; de Boer, et al., 2001; Yang & Chen, 2006).

The whole classification of the different methods inside the five categories can be found in Table 8.

Category	Method
MCDM/ Linear weighting models	Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Outranking methods, Multiple Attribute Utility Theory (MAUT), Linear weighted point, Judgemental modeling, Interpretative Structural Modeling, Categorical methods and Fuzzy sets.
Artificial intelligence & Expert Systems	Neural Networks, Case-Based Reasoning, Bayesian Belief Networks.
Multivariate Statistical/probabilistic approaches	Structural Equation Modeling, Principal Component Analysis, Factor Analysis, and Confident Interval Approach.
Mathematical programming	Total cost based approaches, Linear and Non-linear programming, Integer programming, Goal programming, Heuristics, Mixed integer programming, and Data Envelopment Analysis (DEA).
Total cost based	Total cost of ownerships (TCO), Activity Based Costing (ABC)
Other decision making tools	Group decision making and Multiple Methods.

TABLE 8 - LIST AND CLASSIFICATION OF DECISION MAKING METHODS. *SOURCE: (SONMEZ & MAHMUT, 2006) INTEGRATED WITH YANG (2006) AND AGUEZZOUL (2007)*

4.2 DESCRIPTION OF THE MAIN SELECTION MODELS

In this section I will describe the main selection models adopted in the literature. To select the most popular ones I followed this methodology:

- I checked the literature on supplier selection problem from 2007 to 2012. The total number of papers found suitable for the purpose is 45;
- I integrated the remaining years, from 2006 to 1966, with the previous literature review performed by Sonmez (2006). The number of papers in this case is 147.

The results of these two researches can be seen in Table 9.

Most popular selection models

From 1966 to 2006		From 2007 to 2012	
Name	**Percentage**	**Name**	**Percentage**
Total cost based approaches	10.9%	Analytic Hierarchy Process (AHP)	34.8%
Analytic Hierarchy Process (AHP)	6.8%	Analytic Network Process (ANP)	15.9%
Case-Based Reasoning	5.4%	TOPSIS[8]	8.7%
Group decision making	5.4%	Delphi method	5.8%
Data Envelopment Analysis (DEA)	3.4%	Benefit-opportunity-cost-risk (BOCR)	4.3%
Heuristics	2.7%	VIKOR model	2.9%
Neural Network	1.4%	Fuzzy preference programming (FPP)	1.4%
Minor contributions	61.2%	Minor contributions	34.8%

TABLE 9 - MOST POPULAR SELECTION MODELS. *SOURCE: PERSONAL ANALYSIS AND (SONMEZ & MAHMUT, 2006)*

Having identified the most popular decision models, I will provide a brief initial explanation of the meaning and usages of them, without entering in the details, but trying to underline the possible applications, as well as strengths and weaknesses of each model.

4.2.1 ANALYTIC HIERARCHY PROCESS (AHP)

> "THE ANALYTIC HIERARCHY PROCESS (AHP) IS A THEORY OF MEASUREMENT THROUGH PAIRWISE COMPARISON AND RELIES ON THE JUDGMENTS OF EXPERTS TO DERIVE PRIORITY SCALES." (SAATY, 2008)

In particular, the model allows deriving "*relative priorities on absolute scales (invariant under the identity transformation) from both discrete and continuous paired comparisons in multilevel hierarchy structures. These comparisons may be taken from actual measurements or from a fundamental scale that reflects the relative strength of preferences and feelings*". (Saaty & Vargas, 1996).

The Analytic Hierarchy Process (AHP) has been developed by T. Saaty (1971,1980) and it's a multiple criteria decision-making tool (MCDM). AHP is one of the most widely used: fields of application vary from planning, to selection the best alternative, resource allocations, conflict solving and optimization (Vaidya & Kumar, 2006). AHP provides the evaluation of the importance of the different criteria referring to a comparison between them; the comparisons are made using a scale of absolute judgments that represents how much one element dominates another with respect to a given attribute (Saaty, 2008).

Before the comparison, the different factors are divided into classes, and the comparison will be made between factors belonging to the same class. This allows the comparison only between criterions belonging to the same nature (in terms of dimension, type and so on).

[8] Technique for order preference by similarity to the ideal solution (TOPSIS)

The process is simple: first the factors has to be divided into a hierarchical structure, identifying classes and attributes. Then the attributes belonging to one class are compared together in pairs. To express numerically this comparison, a scale is used (1: Equal, 3: moderately more, 5: strongly more, 7: very strongly more, 9: extremely more). Then a comparison matrix is created. The process is repeated for all the classes and all the levels, and the final weights are derived using the eigenvalue method (Saaty, 1990).

Saaty (1980) also defined the requirements that the comparison matrixes have to satisfy to be considered valid. The concept is simple: if index A is better than B, and B is better than C, A must be better than C. To check this relationship, the consistency ratio has to be calculated[9], and it must not exceed some particular values: it has to be lower of 5% for 3x3 matrixes, 8% for 4x4 and 10% for bigger ones.

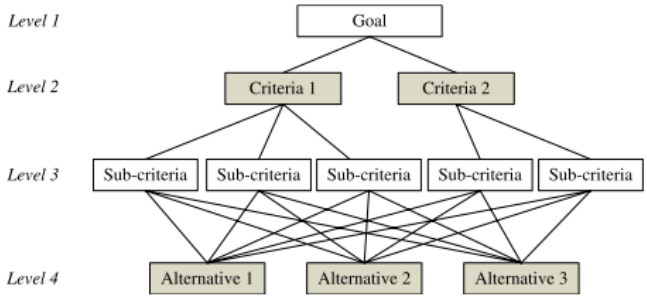


FIGURE 11 - EXAMPLE OF AHP HIERARCHICAL STRUCTURE. *SOURCE: (EFENDIGIL, ET AL., 2008)*

The main strengths deriving from the adoption of and AHP are the followings.

+ The main ones are: flexibility, intuitive appeal to the decision makers and ability to check inconsistencies (Ramanathan, 2001). This method can be integrated with different techniques like Linear Programming, Quality Function Development (QFD) and Fuzzy logics.
+ During the definition of the problem , the decision-maker has to decompose the problem into its constituent parts and build a hierarchy of criteria. Doing this, the importance of each element becomes clear (Macharis, et al., 2004).
+ It can reduce bias in decision making providing mechanism to check the inconsistencies of the evaluations and it supports decision-making through consensus by calculating the geometric mean of the individual pairwise comparisons (Zahir, 1999; Vaidya & Kumar, 2006).
+ It allows users to assess the relative weights of multiple criteria against given criteria providing a rating, or at least, a level of importance. This allows the utilization of this tool also in conditions characterized by risk and uncertainty (Millet & Wedley, 2002).

On the other side, the main weaknesses of the AHP can be summarized in the following lines.

[9] The whole methodology to calculate this index is described in the Methodology part.

- It assumes independency among various criteria of decision-making (Jharkharia, 2007).
- Good scores are compensated with bad scores in other criteria. Due to this aggregation, useful information may be lost or not understood.
- As the number of criteria increases, this comparison can turn out to be very long and time consuming. If *n* is the number of criteria, the total number of comparison will be $\frac{n*(n-1)}{2}$ (Macharis, et al., 2004).
- During the comparison, the decision-maker has to assign a value of importance of one attribute compared to another one. This value has to rely on the 9-point scale explained before. The problem is that sometimes it is difficult to distinguish the specific value within the scale.

MODIFICATIONS OF THE AHP MODEL

Some authors tried to create some alternative versions of AHP in order to face with its main disadvantages.

Fuzzy AHP – This is the most common modification of AHP. This method combines AHP with fuzzy number theory[10]. The adoption of a fuzzy AHP model, is due to the fact that for decision-makers it's more confident to give an interval judgment than a fixed-value judgment. This is because the decision-maker is unable to explicit his preferences due to the fuzzy nature of the comparison process (Buyukozkan, et al., 2008). The adoption of a fuzzy AHP allows "*to obtain more decisive judgments by prioritizing the supplier selection criteria and weighting them in the presence of vagueness in Phase 1 (Problem decomposition)"* (Efendigil, et al., 2008).

Benefits, Opportunities, Cost and Risks (BOCR) – This method organizes the criteria according to four main categories: benefits, opportunities, costs and risks. In this configuration, benefits and opportunities will have a positive impact on the evaluation, while costs and risks will have a negative one (Lee, 2009).

Fuzzy Preference Programming (FPP) – This method was proposed by Mikhailov (2002) and tries to deal with the uncertainty in judgments deriving characteristics of human beings: the FPP method uses fuzzy numbers and it can be used to derive priority vectors from a set of crisp or interval comparisons. The assessment of the priorities is an optimization problem, maximizing the decision-

[10] "Fuzzy numbers are one way to describe the data vagueness and imprecision. They can be regarded as an extension of the real numbers." (Nasseri, 2008). In the literature there is a shortcoming in the definition of fuzzy number. In general it can be stated that a fuzzy number is an extension of a regular number in the sense that it can assume a value connected to a set of possible values, where each value has its own weight between 0 and 1. This weight is called the membership function.

maker's satisfaction with a specific crisp priority vector (Wang, 2007). Furthermore, this method transforms the pairwise comparison problem into a linear programming one (Mikhailov, 2002).

4.2.2 ANALYTIC NETWORK PROCESS (ANP)

> "THE ANALYTIC NETWORK PROCESS (ANP) IS A MULTI CRITERIA THEORY OF MEASUREMENT USED TO DERIVE PRIORITY SCALES OF ABSOLUTE NUMBERS FROM INDIVIDUAL JUDGMENTS (OR FROM ACTUAL MEASUREMENTS NORMALIZED TO A RELATIVE FORM) THAT ALSO BELONG TO A FUNDAMENTAL SCALE OF ABSOLUTE NUMBERS. THESE JUDGMENTS REPRESENTS THE RELATIVE INFLUENCE, OF ONE OF TWO ELEMENTS OVER THE OTHER IN A PAIRWISE COMPARISON PROCESS ON A THIRD ELEMENT IN THE SYSTEM, WITH RESPECT TO AN UNDERLYING CONTROL CRITERION." (SAATY, 2004)

As stated before, one of the limitations of AHP is that is assumes the independency among various criteria of decision-making. The Analytic Network Process (ANP) "*captures the independency among the decision attributes and allows a more systematic analysis*" (Jharkharia, 2007). This result is possible using a super matrix, whose entries are themselves matrices of column priorities.

If the AHP is characterized by a hierarchical structure, the ANP structure is more like a network, without the need of specify levels. The fundamental scale used in the AHP model is used again, but in this model two questions has to be answered:

1. Given a criterion, which of two elements is more important with respect to that criterion?
2. Which of two elements influences a third element more with respect to a criterion?

Saaty 2004 also underlined that this method is applicable to several fields, such as physical world (for example gravitational pull), biology (giving birth or dying), psychology (loving and hating) and politics (persuading, negotiating and opposing). Given the tight link with reality, it's easy to understand why ANP is so popular among selection models (Saaty, 2004).

In order to check that all these influences have been considered with respect to the same criterion, the control hierarchy is defined and provides overriding criteria for comparing each type of interaction that is intended by the network representation (Gencer, 2007).

As can be seen in Figure 12, AHP method is characterized by a defined goal at the top, and then a linear top down structure with no feedback from lower to higher levels. The loop at the lower level indicates that the alternatives in that cluster only depend on themselves and the cluster is considered independent from the others.

FIGURE 12 - AHP STRUCTURE. *SOURCE: (SAATY, 2004)*

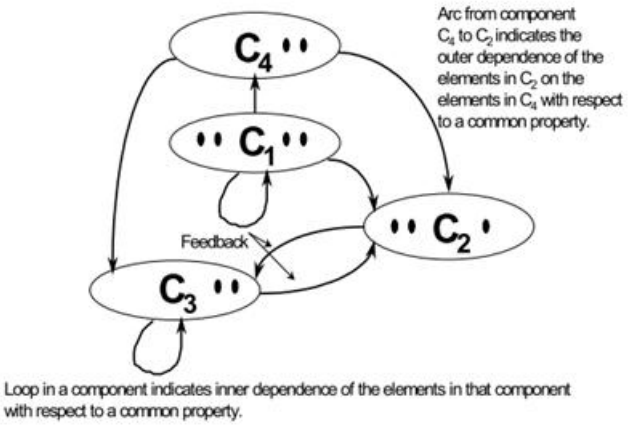


Figure 13 shows that ANP is more like a network spread out in all directions. It can also be noticed that the cluster of elements are not arranged in a particular order. In this way, both inner (inside the cluster) and outer (among clusters) independences are possible.

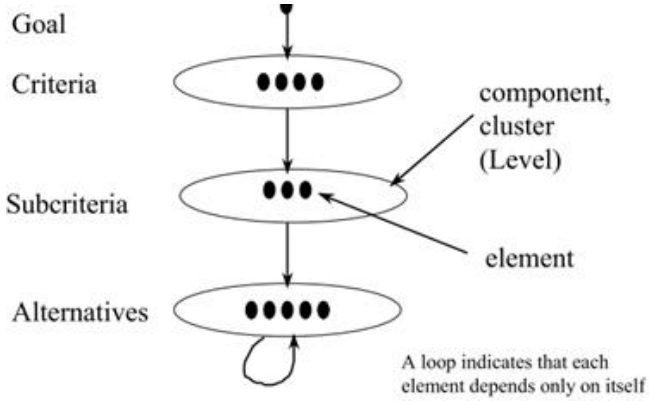


FIGURE 13 - ANP STRUCTURE. *SOURCE: (SAATY, 2004)*

Strengths and weaknesses - Due to the tight similarity to AHP, there is no need to underline strengths and weaknesses again. The only relevant change is that, as ANP does not assume independency between categories, one weakness of AHP is cancelled.

4.2.3 TOTAL BASED COST APPROACH

Traditionally, the evaluation of supplier selection has been made basically considering only the direct price: the cheapest supplier was selected, without considering all the potential deriving costs. That approach has been confuted by scholars, who underlined the need to gain an insight of the total cost generated by external purchasing (Degraeve & Roodhooft, 1999).

> THE TOTAL BASED COST APPROACH, IS A METHOD IN WHICH "THE QUOTED PRICE FROM EACH SUPPLIER IS TAKEN AS THE STARTING POINT AND THEN EACH ISSUE BEING CONSIDERED IS REPLACED BY A COST FACTOR". (BHUTTA, ET AL., 2002)

The process begins with the definition of the important factors to the organization, then each factor is translated into a cost component and it's added to the price formula. The last step is to assign a debit (or a credit) for each factor that is appropriate to that supplier's performance.

In the literature, several cost based methods have been defined, the most important is the Total Cost of Ownership (TCO).

TOTAL COST OF OWNERSHIP (TCO)

> "TOTAL COST OF OWNERSHIP ATTEMPTS TO QUANTIFY ALL OF THE COSTS RELATED TO THE PURCHASE OF A GIVEN QUANTITY OF PRODUCTS OR SERVICES FROM A GIVEN SUPPLIER." (DEGRAEVE & ROODHOOFT, 1999)

As typical in the total based cost approaches, price is the initial important component. In addition to the price component, other cost factors have to be considered: first of all the availability of discounts, then costs associated with quality shortcomings or supplier's unreliable delivery; other possible sources of costs can be transportation costs, ordering costs, administrative costs, communication costs, maintenance costs, reception costs and inspection costs. The final comparison and selection of the supplier to be chosen is made using a mathematical method to minimize the total cost (Degraeve & Roodhooft, 1999).

The main strengths deriving from the adoption a TCO approach can be found below.

+ There is no more the problem of the quantification of the criteria and the trade-off between them because the solution is directly referred to a specific supplier.
+ The objective cost measure is achieved in a systematic way and once the cost system is developed, the company can exploit it to develop inter-organizational activity based management opportunities and increase the quality of the relationship with suppliers.
+ It specifies in detail all the costs, thanks to this, a sensitive analysis on all the cost dimension can be done: the impact of different alternatives, the variation of the quantities purchased, and the consequences of productivity improvements can be calculated and quantified.

On the other side, TCO's main weaknesses can be indentified in the following points.

- An extensive management system is required. Furthermore it's complex to set up and to use.
- It's difficult to use in context in which subjective assessments and judgments have to be used in comparing factors.
- It's too focused on cost dimensions and does not consider qualitative data (Bhutta, et al., 2002; Degraeve, et al., 2000).

4.2.4 OTHER MINOR METHODS

Delphi method - "The Delphi method accumulated and analyses the results of anonymous experts that communicate in written, discussion and feedback formats on a particular topic." (Chang, et al., 2008). The main strengths of this method are that it can achieve consensus in a given area of uncertainty or lack of empirical evidence, the system of feedbacks can stimulate new ideas and, if performed in a written form, it can be done without physical presence (Delbecq, et al., 1975). The main weaknesses are that a suboptimal solution may be achieved, extreme views, in a positive and negative way, are eliminated, anonymity can lead to a lack of accountability and the group of people may not be representative (Sackman, 1975).

Case-Based Reasoning (CBR) - "Case-Based Reasoning (CBR) approach is a method for solving problems by making use of previous similar cases" (Faez, 2009). CBR systems are developed by knowledge engineers who interview one or more managers to catalog their experiences. CBR's philosophy is to solve problems by using problem-solving experiences of humans: the process can be compared to an expert who uses his own experiences on past cases to solve new problems. At the basis of this model there is a knowledge system that contains a library of classified problem-solving experiences, the manager can question the system and get the answers needed (Cook, 1997). The strength of this method are that it can be applied to problem domains not well understood, a continuous updating of the system can force rapid knowledge acquisition and maintenance and the solutions is provided rapidly. Disadvantages are linked to the fact that the solution is based on past cases: innovative ideas are hidden, the solution basis must be wide and updated, and the quality of the solution depends also on the indexing system (Cook, 1997).

Technique for order preference by similarity to the ideal solution (TOPSIS) and VIKOR methods - TOPSIS and VIKOR[11] are two similar methods. They can be defined as follows. "VIKOR method focuses in ranking and selecting from a set of alternatives, in the presence of conflicting criteria, basing on closeness to the ideal solution. It determines the compromise ranking-list, the compromises solution, and the weight stability intervals for preference stability of the compromise solution obtained with the initial (given) weights." (Opricovic & Tzeng, 2004). "The basic concept of TOPSIS is that the rank of the alternatives selected as the best from a set of different alternatives should have the shortest distance from the ideal solution and the farthest distance from the negative-ideal solution in a geometrical sense". (Buyukozkan, et al., 2008). VIKOR and TOPSIS are both distance-based methods, the main difference is that VIKOR method calculates the weighted distance from one point, the ideal-solution, while TOPSIS method does not include any weights, but it calculate the distance from two

[11] From the Serbian name: VlseKriterijumska Optimizacija I Kompromisno Resenje, meaning multi-criteria optimization and compromise solution. Source: (Sanayei, et al., 2010).

points: the best-ideal solution and the negative-ideal solution. (Opricovic, 2007; Sanayei, 2010). The strengths are: sound logic, simultaneous consideration of the ideal and the anti-ideal solutions and easily programmable computation procedure (Buyukozkan, et al., 2008) and VIKOR method includes the possibility to assign and analyze weights on proposed compromise solution (Opricovic & Tzeng, 2004). The weaknesses are that they require quantitative attributes expressed as crisp numbers (Buyukozkan, et al., 2008) and that TOPSIS considers two points (best and worst solutions) but it does not include their relative importance (Opricovic & Tzeng, 2004).

4.3 CONCLUSIONS

Scholars and researchers have used several different methods in their works, frequently modifying the already existing ones to better answer their specific needs. Each specific method has strengths and weaknesses, and for this reason the decision of which method to use depends on the environment: the AHP/ANP family can be used in risk and uncertainty frameworks, the TCO is good for stable conditions for which the main driver is cost, Delphi method is useful when there is uncertainty but experts are available. If good records of previous cases are available, CBR, TOPSIS and VIKOR may be used too.

Among all, the most used ones belong to the AHP family: it is quite simple to use, the methodology is mature and strengths and weaknesses are clearly defined.

5. MODERN WORKS ON SUPPLIER SELECTION

After having analyzed the history of supplier selection, summarizing contributions from 1966 to 2006, I will now try to revise the latest researches on the subject, in order to derive the most important selection criteria for the development of the supplier selection model.

5.1 METHODOLOGY

The methodology I've followed can be summarized as comes.

1. First, I read and classified the research works from 2007 included to 2012. 55 articles have been found. The classification has been done diving the works according to two dimensions:
   a. The selection model adopted: AHP, BOCR, FPP, ANP, Delphi, VIKOR and TOPSIS were the most used, while other papers followed minor models. It has to be stated though, that it is very difficult to find a single selection model in each specific work, the most common and frequent used solution is to combine at least two models together, or to repeat the analysis using different models.
   b. The contest of adoption: the first type of distinction was between supplier selection adopted for service selection, and supplier selection model adopted for material suppliers selection. Within these two main branches, other dimensions were identified. For example, inside the service dimension the most relevant contributions (in terms of numbers) were related to 3PL selection, while in the material purchasing part, great attention was given to automobile industry and supplier selection in general.

   The result of this classification can be seen in the table in the following page. Note that, in case of different methods used in the same analysis, the predominant one is written in normal style, while the secondary one in italic.
2. Second, I tried to analyze the single contribution in a systemic way: the greatest attention was given to the papers belonging to the AHP-service category: for these papers I carefully analyzed and synthesized the approach and the selection criteria adopted. Then, another main part of this section was dedicated to the other AHP contributions (material purchasing) and, given the similarities already stated, to ANP, BOCR and SPP models. For the remaining papers, I just showed the main findings emerged from the researches.

TABLE 10 (FOLLOWING PAGE) - PAPER CLASSIFICATION

B.1 – Supplier Selection

Application Context		Method used								TOT
		AHP	BOCR	FPP	ANP	Delphi	VIKOR	TOPSIS	Others	
Supplier selection – Services	General considerations								(Zhang & Chen, 2009)	**1**
	3PL	(Liu & Wang, 2009; Efendigil, et al., 2008; Percin, 2009; Bhatti, et al., 2010; Vijayvargiya & Dey, 2010)	(Sun, et al., 2010)		(Jharkharia, 2007; Chen & Wu, 2011; Sun, et al., 2010)	*(Liu & Wang, 2009; Percin, 2009; Chen & Wu, 2011)*		*(Percin, 2009)*	(*Efendigil, et al., 2008*; Li, et al., 2012; Lao, 2011)	**13**
	e-logistic	(Buyukozkan, et al., 2008)						*(Buyukozkan, et al., 2008)*		**1**
	e-provider								(Das & Buddress, 2007)	**1**
	Internet S. Provider								(Amin & Razmi, 2009)	**1**
	Professional Services								(Sonmez & Moorhouse, 2010)	**1**
	IT/IS services	(Chang, et al., 2010)				*(Chang, et al., 2010)*				**1**
Supplier selection – Material (classified by industry)	General considerations	(Chan, et al., 2008)							(Lam, et al., 2010; Bai & Sarkis, 2010; Liao & Rittscher, 2007; Ng, 2008; Yeh & Chuang, 2011; Ha & Krishman, 2008)	**3**
	Automobile	(Zeydan, et al., 2011)						(*Zeydan, et al., 2011*; Boran, et al., 2009)	(Amin, et al., 2011; Zeydan, et al., 2011)	**7**
	Computer industry								(Chou & Chang, 2008; Huang & Keskar, 2007)	**2**
	Steel	(Koul, et al., 2011; Chamodrakas, et al., 2010)		(*Chamodrakas , et al., 2010*)						**1**
	Electric				(Vinodh, et al., 2011)					**1**
	Textile								(Araz, et al., 2007; Shaw, et al., 2012)	**2**
	Air conditioner	(Aydin & Kahraman, 2010)								**1**
	Material Plastic Molding		(Demirtas & Ustun, 2008)		(*Demirtas & Ustun, 2008*)					**1**
	Appliances								(Sevkli, et al., 2007)	**1**
	Washing machine	(Kilincci & Onal, 2011)								**1**
	Telco				(Onut, et al., 2009)			(*Onut, et al., 2009*)		**1**
	Refrigerator		(Ustun & Demirtas, 2008)		(*Ustun & Demirtas, 2008*)					**1**
	High tech	(Ting & Cho, 2008)								**1**
	Construction				(Ebrahimnejad, et al., 2011)		(*Ebrahimnejad, et al., 2011*)			**1**
Other works	Outsourcing providers	(Liou, et al., 2011)		(*Liou, et al., 2011*)	(Liou & Chuang, 2010; *Liou, et al., 2011*)		(*Liou & Chuang, 2010*)			**2**
	Vendor selection								(Faez, 2009)	**1**
	Performance evaluation	(Ertugrul & Karakasoglu, 2009)						(*Ertugrul & Karakasoglu, 2009*)		**1**
	General considerations on supplier selection	(Xia & Wu, 2007)	(Lee, 2009)		(Razmi, et al., 2009)				(Amid, et al., 2006; Billhardt, et al., 2007; Tan, et al., 2008; Yang & Chen, 2006)	**8**
TOT		**17**	**4**	**2**	**11**	**4**	**2**	**6**	**25**	**55**

5.2 SUPPLIER SELECTION FOR SERVICES

As declared in the introduction part, the greatest attention of the researchers has been paid for the selection of the supplier for the purchasing of tangible materials. In the limited works dedicated to the selection of the best service supplier, the main attention was dedicated to 3PL provider selection. As regard the selection models, the most popular is, coherent with the global trend, the AHP model, followed by ANP and Delphi method.

5.2.1 ANALYTIC HIERARCHY PROCESS

The authors that dealt with the service supplier selection problem, using AHP methods are 7: 5 have analyzed the 3PL selection (Efendigil, et al., 2008; Liu & Wang, 2009; Percin, 2009; Vijayvargiya & Dey, 2010; Bhatti, et al., 2010), one had considered the problem referred to e-logistic context (Buyukozkan, et al., 2008) and another one performed an analysis of supplier selection for IT/IS outsourcing providers for Small-and Medium-size enterprises (Chang, et al., 2010).

The first contribution considered is the one by Efendigil, et all (2008). They considered a holistic approach for selecting a 3PL provider for reverse logistics services. The selection criteria identified are taken and adapted from Kongar's (2005) and they include both qualitative and quantitative criteria. The selection models adopted were a fuzzy AHP combined with an Analytic Neural Network (Efendigil, et al., 2008).

Efendigil, et al. (2008) with reference to Kongar (2005)

Criterion	Description	Priority weight[12]
Environmental expenditures	Cost of environmental activities	0.1321
Integration level index	Level of integration among customer and company	0.1255
System flexibility index	Flexibility index required	0.1176
Unit operation cost	Cost spent for unit transported	0.1110
Service quality level	Quality level of service requested by the customer	0.0911
Total order cycle time	Time elapsed from the beginning to the end of the reverse process	0.0885
On time delivery ratio	Amount of orders delivered no later than the delivery day request on the total amount of orders	0.0845
Customer satisfaction index	Ratio between satisfied customers and the total number	0.0819
Confirmed fill rate	Ratio between "right amount and right size" delivery and the total	0.0753
R&D ratio	Ratio between R&D expenses and total cost	0.0700

[12] The higher the weight, the more important the criterion.

The 3PL supplier selection model, applied to a medium-size company in Taiwan, is the focus of the research from Liu & Wang (2009). The criteria adopted in their work were taken from different sources, and can be find the following table. At the end of their analyses, Liu & Wang noticed some relevant issues: first of all they identified the subjectivity of the decisions and the evaluations; then they stated that the results of their work was strongly dependent on the specific situation, and finally they underlined that several data were provided by the supplier itself, making different on-site inspections mandatory for the objectivity of the process (Liu & Wang, 2009).

Liu & Wang (2009)

Rank	Criterion	Rank	Criterion
1	Logistics information system	10	Logistics equipment
2	Customer service	11	Price
3	On-time shipment and deliveries	12	Experience in the similar industry
4	Responsiveness	13	Service quality
5	Capability to handle specific business requirements	14	Continuous improvement
6	Accessibility of contract people in urgency	15	Cultural fit
7	General reputation	16	EDI capacity
8	Location	17	Value-added service
9	Market share		

In 2010, Bhatti, et al. performed a research on supplier selection services for Lead Logistics Providers (LLP)[13]. In order to define the selection criteria to be used, they prepared a questionnaire and discussed the results with five expert academics. The resulting sixteen criteria were then divided into four main categories: *vendor status*, *logistics competence, quality of service* and *IT-based competences*. Then, the AHP model was applied and the weights derived (Bhatti, et al., 2010).

Bhatti, et al. (2010)

Rank	Category	Criterion	Rank	Category	Criterion
1	Vendor status	Scale of operations	9	Logistics competence	Throughput capabilities
2		Operational boundaries	10	Quality of service	ERP competence
3	Logistics competence	Logistics technology	11		Time to transport
4		Logistics apparatus	12		Scope of services
5	Vendor status	Local market ranking	13	IT-based competencies	IT-enabled network
6		Global market ranking	14		EDI facilities
7	Logistics competence	Maintenance cost	15		Achievement monitoring capabilities
8	Quality of service	Article of trade wastage	16		Processed data handling capabilities

[13] *" The LLP is a logistics chain integrator who synchronizes and manages the resources, capabilities and technology of its own organization with those of complementary service provider to deliver a comprehensive supply chain solution"* (Xu, 2002). The LPP leverages on the competences of 3PLs and business process managers to deliver an integrated supply chain solution acting like a point of contact (Bhatti, et al., 2010).

A further contribution was given by Percin (2009): in his work he analyzed the 3PL selection problem related to a Turkish manufacturer inside the automotive industry. Percin used the Delphi method to select and evaluate the selection criteria to be adopted; during the meetings, 13 experts were involved in the process. The selected indicators were then classified in three main categories: strategic factors, *business factors* and *risk factors*. Percin identified also some limitations to his work: first of all he stated that other factors could have been integrated, for example business experience, geographic location, reliability, reputation, delivery time, IT infrastructure, training systems, and customer service. Second, including these new criteria, the weights have to be calculated again. Finally, the development of the model, and in particular the definition of the relative weights, strongly depends in the decision makers involved in the process (Percin, 2009).

Percin (2009)

Rank	Category	Criterion	Rank	Category	Criterion
1	Business	Market Knowledge	7	Strategy	Compatible culture
2	Business	Performance	8	Business	Management capacity
3	Strategy	Financial Stability	9	Strategy	Strategic partnerships
4	Business	Technical ability	10	Strategy	Similar values-goals
5	Risk	Loss of functional control	11	Risk	Complexity in operations and delivery
6	Risk	Risk in choosing the right partner	12	Strategy	Similar size

The indicators belonging to business and strategy category, has been used also by Buyukozkan, et al. in 2008, even though the focus of this research was different: Buyukozkan, et al. tried to define a selection model to define strategic partners for an e-logistic system. Even if the criteria were partially the same, the ranking is different, this is a demonstration of the dependence of the model to the specific situation (Buyukozkan, et al., 2008).

Buyukozkan, et al. (2008)

Rank	Category	Criterion	Rank	Category	Criterion
1	Strategy	Financial Stability	6	Business	Performance
2	Strategy	Sustainable relationship	7	Strategy	Similar size
3	Business	Technical ability	8	Strategy	Compatible culture
4	Strategy	Similar values-goals	9	Business	Market Knowledge
5	Strategy	Successful track record	10	Business	Managerial Experience

The latest contribution regarding the usage of AHP in the service supplier selection process, is referred to Vijayvargiya & Dey (2010). They studied the 3PL provider selection for an automotive company. This company has to select a provider in order to guarantee export-import logistics, warehousing, packaging and value added services. The criteria selected were grouped into three categories: *cost, delivery* and *value added services* (Vijayvargiya & Dey, 2010).

Vijayvargiya & Dey (2010)

Rank	Category	Criterion	Description & considerations
1	Cost	Inland transport and other costs	Measures the competitiveness of the price offer proposed
2	Delivery	Schedule flexibility	Ability to meet varying market demand. If a 3PL has a good flexibility, it can offer cheaper rates as well as on time delivery
3	Cost	Ocean/Air freight	Cost to deliver goods through ocean or air. This dimension depends also on the flexibility and the solution chosen
4	Value added services	Clearing & forwarding	This aspect is very important in case of critical consignment.
5		IT-Track & trace	IT system is very important to easily track the consignments in case of both ocean and air transportation modes
6		Warehousing	Availability of flexible and cheap warehousing is very essential to reduce cost of the total supply chain
7	Delivery	Port licensing, set up and presence	This aspect is important for ensuring the on time delivery of consignments

Supplier selection is not only limited to 3PL selection: Chang, et al. (2010) performed an analysis of supplier selection for IT/IS[14] outsourcing providers for Small-and Medium-size enterprises in Taiwan. Chang et al, used a combination of Delphi method and AHP; the first one was used to interview 20 experts in order to derive the classification factors and the selection criteria, while the second one was used to derive the prioritization and the relative weights. The discussion highlighted four main categories, that, in order of importance, are: *capacity of professional skills* (30%), *capacity of service* (27%), *capacity of operation* (21%) and *external evaluation* (21%) (Chang, et al., 2010).

Chang, et al. (2010)[15]

Rank	Category	Criterion	Absolute weight
1	Capacity of service	Service, relationship, and support of contractors	0.20
2	External evaluation	Knowledge on the clients' industry	0.15
3		Reputation	0.15
4	Capacity of service	Completeness of system document, manuals, and process improvement capability	0.11
5	Capacity of professional skills	Property, quality and reliability of products	0.07
6		Capacity for system integration	0.06
7		Information security techniques	0.05
8		Capacity for research and development	0.04
9		Development tools of the system	0.03
10		Software and hardware capacities	0.02

[14] Information Technology and Information System
[15] For a detailed description of each criterion refer to Annexes.

11	Capacity of operation	Maintenance of business confidentiality	0.03
12		Organizational resources	0.03
13		Capacity for specific project management items	0.03
14		Stability of financial affairs	0.03
15		Enterprise culture	0.02
16		Flexibility of contractors in relation to the deadline	0.02
17		Capacity of employees	0.02
18		Lawsuits with clients	0.02
19		Previous cooperation with proprietors	0.02

5.2.2 ANALYTIC NETWORK PROCESS, BOCR AND DELPHI METHOD

This section includes works adopting ANP, BOCR or Delphi methods, and is basically only related to 3PL selection.

A first example of adoption of ANP for 3PL provider selection is given by Jharkharia & Shankar (2007). They first identified 4 main determinants for supplier selection: *compatibility, cost, quality* and *reputation*. Then they defined other 4 dimensions and the relative enablers:

- *long-term relationship* – Performance measurement; willingness to use logistics manpower; flexibility in billing and payment; quality of management; Information sharing;
- *operational performance* – IT capability; Size and quality of fixed assets; Experience in similar products; delivery performance; Employee satisfaction level;
- *financial performance* – Market share; Range of services provided; Geographical spread and access to retailers;
- *risk management* – Surge capacity; Clause for arbitration and escape; Flexibility in operations delivery[16].

The results of the study identified that *compatibility* is the most relevant determinant, followed by *cost*, *reputation* and *quality*. As regards the dimensions, *operation performance* is the most important, second is *long-term relationship*, and then come *financial performance* and *risk management* (Jharkharia, 2007).

Another example of adoption of ANP model is given by Chen & Wu (2011). Their work includes the development of a 3PL supplier selection model, but it's not limited to this aspect: they firstly adopted the ANP method, using Delphi method to define the criteria, and then they compared the results with the ones obtained from an AHP model. The comparison highlighted that there is no great different at category level, even though the interdependence relationships slightly changed the

[16] A detailed description of the selection criteria can be found in the annexes.

weights. Bigger differences can be seen, instead, at single criterion level. The two different rankings can be seen in the following table (Chen & Wu, 2011).

Chen & Wu (2011)

Category	Criterion	Rank with ANP	Rank with AHP
Cost	The cooperation with our customer	1	1
Cost	Price	2	3
Quality	On-time delivery	3	2
Cost	Enhanced operational efficiency	4	5
Quality	The ability of goods preservation	5	6
Logistics technology	The ability of goods tracking	6	4
Quality	Surge capability	7	8
Quality	Delivery conforms to regulation	8	13
Operational Performance	IT system capability	9	7
Operational Performance	Developing long-term relationship	10	9
Operational Performance	Flexibility in logistic service	11	10
Operational Performance	Delivery performance	12	11
Operational Performance	Transactional Field	13	14
Logistics technology	Employee performance	14	16
Company Performance	Financial conditions	15	12
Company Performance	Accumulating experience	16	15
Company Performance	Industry reputation	17	17
Company Performance	Fitness of geographical location	18	18

One of the few examples of BOCR application is the research from Sun, et al. (2010). They dealt with the 3PL provider selection organizing the twelve criteria in four main dimensions: *benefits* (B), *opportunities* (O), *costs* (C) and *risks* (R). Then they applied the ANP method to derive the weighs and select the best alternative. The criteria identified are as follows (Sun, et al., 2010).

Sun, et al. (2010)

Benefits	***Opportunities***
• On- time delivery rate • Accurate delivery rate • Efficiency of ordering processing	• Service scope • Volume of business • Operating experience
Costs	***Risks***
• Service price • Transaction price • Variable cost	• Data security • Information accuracy • Staffing level

5.2.3 OTHER WORKS IN SERVICE ENVIRONMENT

As I already said, in addition to the main selection models, there are several single contributions that can be useful to have a global picture of the subject.

Li, et al. (2012) applied a comprehensive evaluation model of 3PL providers based on fuzzy value satisfaction and established a comparison method based on synthesis effect. The result was to identify and rank 4 main categories plus several second-level indices that can be found in the annexes. The 4 categories and their weights are: *Service quality* (0.3), *Business strength* (0.25), *Business growth* (0.25) and *Management success* (0.2).
Another relevant contribution given by Li, et al. (2012), is to identify 5 main characteristics that the index system should follow, here comes the list of these requirements.

1. *System considerations*: it should reflect all the aspects of the outsourcing service provider. It should also include opinions coming from the contractor and should include both qualitative and quantitative measures.
2. *Objectivity*: it should reflect the main features and characteristics of the outsourcing service provider.
3. *Scientific basis*: it should have high generality and be able to highlight priorities.
4. *Independence propriety*: it should avoid concept overlapping and statistical dependencies of individual indexes.
5. *Forward-looking property*: it should reflect possible strategic considerations (Li, et al., 2012).

A survey (with 200 responses) was performed in 2011 by Lao, et al. to investigate the relationship between the reasons for using 3PL services and the requirements for selecting a provider; further attention was placed on the relationship between customer satisfaction and loyalty. The variable and the factors identified can be seen in the following table. The results underlined that, especially for Small enterprise, *reputation* is the most important factor affecting the choice, followed by *service quality*. Lao, et al. discovered also that the satisfaction with the level of quality is the main source of loyalty, and this increase is more present in the loyalty side rather than in the reputation side. Another important aspect emerging in the recent years is the attention on environmental aspects: more companies prefer to embrace the element of “green” in their operations, selecting “greener” 3PL providers (Lao, 2011).

Different factors and variables. (Lao, 2011)

Focus	Factor	Variables
Reason for using 3PL	Quality improvement	Improve process responsiveness, service quality, process lead time and cycle time; Increase supply chain flexibility.
	Cost	Logistics cost reduction; Avoiding the investment on logistics

	reduction	services; Help to focus on core business.
Requirement for selecting 3PL providers	Service quality	Increase picking and dispatching accuracy; Lower % of damages; Lower error rate; Quick response to customer enquiries and complaint; Overall responsiveness.
	Reputation	Financial stability; Prior relationship with the company; Information sharing; General reputation; Improve process lead time; Improve cycle time.
Customer loyalty to 3PL providers	Primary customer loyalty	Consider 3PL as the first choice; Do more business with 3PL in the next future; Say positive things to colleagues; Recommend 3PL to colleagues; Use 3PL regardless the price; Use 3PL even if other methods are lower in price.
	Complaints	Make a complaint to other manufacturer if there is a problem with 3PL service; Discourage other manufacturer from using 3PL services.

A specific attention to e-projects was paid by Das & Buddress (2007). They performed a clustering analysis and ANOVA[17] on data collected by 103 companies. In particular they analyzed the difference between tangible and intangible factors affecting supplier selection. The result highlighted a strong predominance of intangible factors over tangible ones. Here comes the list of the 10 most important criteria for e-project in order of importance: *provider product technology; provider strategic fit; service track record; customer references; trust in provider; implementation time; ease of migration path; industry experience; low maintenance cost and low scalability cost* (Das & Buddress, 2007).

Amin & Razmin (2009) created a model to manage the selection process as a whole: from the selection, to the evaluation, ending with the supplier development. They applied a QFD[18] model for the first steps, and then an evaluation one based on fuzzy set theory. Furthermore, this new method was applied to the selection of ISP[19], that they claimed to be a relatively new contest. In order to decide the evaluation criteria, Amin & Razmin set up several meetings with experts, and came up with 13 criteria, divided in 3 categories (Amin & Razmi, 2009):

Amin & Razmin (2009) supplier selection and evaluation criteria.

Service related	**Supplier related**	
	Qualitative criteria	Quantitative criteria
• Accessibility • Reliability • Security • Speed	• Effective marketing & promotion • Experience • Financial Strength • Management stability • Strategic Alliances • Support resource	• Monthly fee • Supply variety • Installation fee

[17] Analysis of Variance
[18] Quality Function Deployment
[19] Internet Service Provider

The last work belonging to the service world is regards the selection of professional services, targeted by Sonmez & Moorhouse (2010). They based their research on 24 face-to-face interviews with experts and 309 online surveys and they identified 37 criteria organized in 6 "high level" dimensions. Then they applied statistics and exploratory factor to analyze the data and determine the weights. In the following table, the ranking of the high level dimensions, the first and last three sub-criteria can be found.

Sonmez & Moorhouse (2010)

High level dimension		Sub-criteria	
Rank	**Dimension**	**Rank**	**Criteria**
1	Competence	1	Meet client's needs
2	Knowledge and understanding	2	Ability to change value
3	Product	3	Bring added value
4	Reputation	35	Publications
5	Organizational capability	36	Size (revenues)
6	Cost	37	Lowest Price

The research by Sonmez & Moorhouse did not stop here; they applied an orthogonal rotation method (varimax) to the data, and discovered that the 37 criteria could be clustered into 11 factors, which are: *product features; reputation; international capability; experience; ability to measure training effectiveness; relationships; organizational capability; knowledge and understanding; reference; product value;* and *others* (Sonmez & Moorhouse, 2010). For a complete overview of the criteria, please refer to the Annexes.

5.3 SUPPLIER SELECTION FOR MATERIAL PURCHASING

The majority of the researches addressed the supplier selection problem considering a manufacturing focus: the items purchased are tangible goods and materials. Within this field, even though there are different authors who considered the selection problem "in general", several examples of application in different industries were created, with a slight predominance of the automotive industry. As regards the methods adopted, the pattern is coherent with the service field, with a higher attention towards AHP and ANP, and with several minor methods adopted.

In this section I will follow the structure already adopted before, that is to analyze carefully the papers adopting the AHP method, then I'll analyze the ones with ANP, and finally I will present a sum up of the other works.

5.3.1 ANALYTIC HIERARCHY PROCESS

A general overview of supplier selection in material purchasing is given by Chan, et al. (2008). In their works, they analyzed carefully the supplier selection with an international focus, trying to define criteria that consider the capability of the supplier to operate worldwide reducing the risks (note that this research was strongly influenced by 9/11 events). Supplier selection criteria were identified from literature and experts' evaluation; then fuzzy AHP was applied to give a weight to each category and sub-criteria. 5 main domains were identified (in order of importance): *total cost of ownership, quality, service, background of supplie*r and, at the end, *risk factors*. Each criterion, with the relative rank, can be seen in the following table (Chan, et al., 2008).

Chan, et al. (2008)

Rank	Category	Criteria	Rank	Category	Criteria
1	Cost of ownership	Product cost	11	Risk factors	Exchange rates and economic position
2		Total logistics management cost	12	Quality	Quality assessment technique
3		Tariff and taxes	13	Service	Flexibility and responsiveness
4	Quality	Conformance to specification	14		Customer response
5	Service	Delivery reliability	15		Formation sharing
6	Background	Technological capability	16	Quality	Product reliability
7		Facility and infrastructure	17	Background	Financial status
8	Quality	Process capability	18		Market reputation
9	Risk factors	Geographical location	19	Risk factors	Terrorist and crime rate
10		Political stability and foreign policies			

In addition to those factors, Chan et al. suggest other possible criteria: reliable delivery; corruption perception; currency stability; labor skill; GDP[20] growth rate; political and economic stability; satisfactory order promises; regular communications; communication openness; supplier's believability and honesty; legal claims; ethical standards; attractive credit terms; competitive prices; attractive discounts; after-sales service; cultural similarity; assurance about the handling of problems; existence of a refund policy; positive attitude towards complaints; negotiability; R&D capabilities; Technical know-how; IT experience; supplier representative's competence; existence of IT standards; adaptability to future IT market requirements.

[20] Gross Domestic Product

An example of supplier selection in the automotive sector is Zeydan, et al. (2011). They proposed a new method based on AHP for the first phases of the process, integrated with TOPSIS and DEA[21]. The subject of the study was a Turkish car manufacturer which has to select the best material supplier. In this research both qualitative and quantitative methods were applied; the first ones can be seen in the following table, while the second ones are:

- *Defect ratio* - The rejected part ratio in one million.
- *Warranty cost ratio* – After sales warranty claim ratio according to sales.
- *Quality management* – the evaluation of supplier mentality (Zeydan, et al., 2011).

Zeydan, et al. (2011) qualitative criteria

Category	Criterion
New Project Management	Procedural control for the advanced quality planning for new project parts
	Verification and detailed review of product/process
Supplier Management	Controlling PPAP[22] and PPAP process with the suppliers
	Controlling incoming inspection procedure preparation and implementation
	Controlling sub-vendor (supplier) evaluation system
Quality and Environmental Management	Quality/environment target and achievement control
	Control of safety and 5S issues
	Control of products about damage, FIFO[23] and lot traceability
Production Process Management	Quality document control
	SPC[24] and special characteristic's control
	Working conditions, tool change, parameter set up condition
	Equipment Maintenance system
	Change History Management
Test and Inspection Management	In-process inspection system
	Final Product Control
	Regular Test Plan
	Calibration & Validation System
Corrective & Preventive Actions Management	Problems and preventive actions situation

As regards the steel industry, we have two different works. The first one was done by Koul, et al. (2011) and was a pure example of AHP. Koul, et al. selected and evaluated supplier selection criteria through structured interviews with 2 managers. The criteria identified are the following ones (in order of importance, from the most important one): *Quality; Delivery Time; Technical capability;*

[21] Technique for Order Preference by Similarity to Ideal Solution. Data Envelopment Analysis
[22] Production part approval process
[23] First In First Out
[24] Statistical process control

Cost; Past performance; Flexibility; Financial status; Responsiveness; Innovation; Environment aspect; Training; and *Risk averse* (Koul, et al., 2011).

The second one, with a particular attention on the supplier selection trough electronic marketplace, was performed by Chamodrakas, et al. (2010). They used a modified AHP model based on the Fuzzy Preference Programming (FPP). In this way they managed to alleviate the overload of information deriving from the e-marketplace, reducing the need of inputs and the computation complexity. As a result, 3 main dimensions were identified:

- *Cost* (weight 0.6) – expressed as *potential cost reduction*;
- *Delivery* (weight 0.233) – expressed as *compliance with quality* (0.5) and *compliance with due date* (0.5);
- *Quality* (weight 0.167) – expressed as *rejection rate from quality control* (0.75) and *remedy for quality problems* (0.25) (Chamodrakas, et al., 2010).

In 2012, Aydin & Kahraman applied a fuzzy AHP to an air conditioning firm. What is relevant from their work, unfortunately the ranking is not shown, is the definition of the selection criteria: they performed a literature review, analyzing several contributions and providing a comprehensive view of these criteria:

- *Cost*.
- *Service* – On-Time delivery; Warranty period and insurance; Repair turn round time; Information sharing; Whole year availability; Distribution and storage facility.
- *Quality* – Conformance to specification; Production reliability; Quality assurance certification; Defected rate product; Apparent quality.
- *Supplier firm* – Capacity; Experience and performance; Reputation; Geographical location; Financial status.
- *Flexibility* – Changing order volumes; Changing mix of order items (Aydin & Kahraman, 2010).

The last two examples of AHP applied to supplier selection problem are linked to Kilincci & Onal (2011) and Ting & Cho (2008). The first one applied the model to white goods industry, while the second one analyzed the high tech industry. For Kilincci & Onal, the most important criteria are related to *quality* and *supplier's technical abilities*, while the least important are its *general characteristics* (geographical locations and work style). As regards Ting & Cho, *quality* is of primary important too, followed by *product price*, while the least important are the *financial performances* of the supplier (Ting & Cho, 2008; Kilincci & Onal, 2011).

5.3.2 ANALYTIC NETWORK PROCESS

An example of Fuzzy ANP applied to supplier selection is used in Vinodh, et al. (2011)'s work. They applied this approach to an Indian electronics switches company in order to select the best supplier. During the computation, they identified 16 indexes divided into 5 main dimensions, that were, in order of importance: *business improvement, extent of fitness, quality, service,* and *risk*. The whole model can be found in the Annexes (Vinodh, et al., 2011).

Two different works, from the same authors, applied ANP and multi-objective mixed integer linear programming (MOMILP) models. In these works, Demirtas & Ustun (2008) analyzed the supplier selection problem first for a refrigerator company, and second for a material plastic molding company. When identifying the criteria, they divided the 14 indexes in *benefits*, *opportunities*, *costs* and *risks*, adopting the so called BOCR approach. The indexes identified, and the relative weights, are as follows:

- *benefits* (0.318) – divided into *Quality* (*Low defect rates; Process capability*), and Service (*On-time delivery; Process flexibility; Response to changes*);
- *opportunities* (0.178) – expressed as *Contingency*; *Mutual trust & ease of communication*; *Support to design process*;
- *cost* (0.294) – expressed as *Break in line*; *Measurement and assessment cost*;
- *risk* (0.209) – expressed as *Customer complaints*; *Order delays*; *Unavailability to meet further requirements*.

The second method, the MOMILP one, was used to the order allocation (Demirtas & Ustun, 2008; Ustun & Demirtas, 2008).

ANP combined with TOPSIS was used by Onut, et al. (2009) to select the best supplier for a Telco company. The criteria selected were classified into *cost* and *benefits*. The fist dimension was expressed in terms of *direct cost* and *delivery time (days*), while the second one was identified by *References*, *Quality of the products*, *Institutionality* and *Execution time (years*) (Onut, et al., 2009).

A focus on construction projects was taken by Ebrahimnejad, et al. (2011). They applied the ANP model, combined with VIKOR method to solve the supplier selection problem. With reference to Cheng & Li (2005), they applied an evaluation model based on 19 criteria classified into 6 main categories listed below.

- *Operational* – Staffing; Resource requirement; Project duration; Company objective and policy.
- *Financial* – Profitability; Budget control; Risk/return ratio.
- *Legal* – Legal implications; Governmental regulation/ standard; Terms of contract.

- *Managerial* – Project identification ability; Managerial competence; Conflict resolution.
- *Environmental* – Environmental protection; Public relation; Geographical location; Health and safety.
- *Technological* – Technological know-how; Technological implications (Ebrahimnejad, et al., 2011).

5.3.3 OTHER WORKS IN MATERIAL ENVIRONMENT

As it happened for the service supplier selection, also for the material environment there are different works in which other minor methods have been used. These series of works does not follow a common path, but underlines respectively different aspects of the supplier selection process.

In this paragraph I will summarize the main contributions identifiable from these individual researches.

Amin, et al. (2011) defined a new method based on fuzzy SWOT and fuzzy linear programming. With this method, they were able to consider both internal and external criteria, and apply them to an automotive company. The results underline that the most important criteria were *Unit cost* (0.33) and *Quality* (0.27) for the internal dimension; after them come *On-time delivery* (0.21) and *Management stability* (0.19). For the external side, *Strength of geographical* location (0.46) was the most important, followed by *International communication* (0.33) and *Mutual trust* (0.21) (Amin, et al., 2011).

Araz, et al. (2007) dealt with the supplier selection problem under a strategic point of view: they wanted to provide a model to select a strategic partner for a textile company. In their work they used a fuzzy goal programming (FGP) method to combine 10 different qualitative and quantitative criteria. These indexes were referred to *Financial strength, Managerial capability* (C*apacity utilization; Ratio of university graduates; Reliability; Flexibility* and *Information flow*), *Quality* (*Quality controls*; *Non-damaged items* and *Quality certificates*), and *Delivery performance* (Araz, et al., 2007).

A relatively new method, proposed by Ramanathan (2006) was adopted by Sevkli, et al. (2007) in order to analyze the supplier selection problem for a TV manufacturer. This method consists of an adaptation of AHP in the data envelopment analysis (DEA), the result is called data envelopment analytic hierarchy process (DEAHP). The criteria used were divided in six main categories: *Performance assessment, Human resources, Quality system assessment, Manufacturing, Business criteria*, and *Use of information technology* (the complete set è indexes can be found in Annexes). The results underlined that the most important set of criteria was *Business criteria*, and inside it, *Price* was the most important one. Second came *Performance assessment*, including the most

important *Shipment criterion*, and the least important *Relation costs*. Other relevant indicators were *New product development* and *Up-to-date technology* for the *Manufacturing category*, and *Quality assurance* for the *Quality system assessment* (Sevkli, et al., 2007).

Huang & Keskar (2007) proposed a comprehensive method to integrate supplier selection with strategy. In this model, they included indexes belonging to *Reliability, Responsiveness, Flexibility, Cost and financial, Asset and infrastructure, Safety* and *Environment* (Huang & Keskar, 2007).

A great attention on strategy was also paid by Chou & Chang (2008) with their fuzzy simple multi-attribute rating technique (SMART). Chou & Chang underlined the importance of an alignment between supplier selection and operations management/ Supply Chain strategy. To solve the conflict, they proposed a model based on 10 criteria, where the most important one are *Customer rejection rate*, *Management capability*, and *Technical Problem solving* (the whole ranking is shown in Annexes) (Chou & Chang, 2008).

Lam, et al. (2010) proposed a model based on Fuzzy Principal Component Analysis in order to eliminate the multicollinearity among the supplier's attributes. The model included 12 different indexes classified into 7 dimensions: Cost*, Quality, Service, Buyer-supplier relationship, Assurance of supply, Payment terms*, and *Past performance* (for the whole list refer to Annexes) (Lam, et al., 2010).

Cost, quality, delivery and *flexibility* has been used also by Liao & Rittscher (2007). They applied a multi-objective linear programming model to solve the supplier selection problem in stochastic demand conditions (Liao & Rittscher, 2007). A weighted linear program for the multi-criteria selection problem has been used also by Ng (2008). In this case, the indexes analysed were: *Supply variety*, *Quality*, *Distance*, and *Price* (Ng, 2008).

In the recent days, a greater attention was put towards Green issues. Three researches were dedicated to finding "Green criteria" for supplier selection: Yeh & Chuang (2011), Bai & Sarkis (2010) and Shaw, et al. (2012). In a general sense, "*green supply chain refers to the management between suppliers, their products and environment, that is to say, the environment protection principle is bought into suppliers' management system*" (Yeh & Chuang, 2011). Noci (1997) pointed out that companies should construct efficient management environment and emphasized on integrating the relationships between customers and suppliers (Noci, 1997).

Yen & Chuang, in addition to the standard criteria (including *production cost and time, transportation cost and time and quality*) identified several indexes to evaluate the impact of the firm on the environment, these indexes were divided into 6 main categories: *Green image, Product recycling,*

Green design, Green supply chain management, Pollution treatment cost, Environmental performance assessment.

Bai & Sarkis, with reference to Gauthier (2005), classified the Environmental factors into two main categories: *environmental performances* and *environmental practices*. The first type is deferred to *resource consumption* and *pollution production*, while the second one includes *policies* and *procedures*, such as monitoring discharges and periodical audits (Bai & Sarkis, 2010; Gauthier, 2005). Bai & Sarkis' work was not only limited to environmental factors, but included a comprehensive set of indicators, including *strategic and operational factors*, and *internal and external social factors*. For the complete list of criteria please refer to the Annexes. Shaw, et al. didn't pay too much attention on developing new indicators, by simply added *Green House Emissions* to the traditional *Cost, Quality* and *Lead time* (Shaw, et al., 2012).

5.4 OTHER RELEVANT CONTRIBUTIONS

Beside the papers related to supplier selection for services and materials, there is a sequence of other individual works that can be useful to develop a comprehensive model for supplier selection. In this section I will briefly synthesize these contributions.

Chowdhary & Prakash (2007) generalized the importance of service quality dimensions. With reference to Parasuraman, et al. (1985)'s classification, they defined 6 main attributes to determine service quality. Even though the relative importance of these dimensions can vary a lot depending on the situation of usage, a general ranking can be done: the most important one is *Reliability* (27%), followed by *Assurance* (22%) and *Tangibles* (18%), continuing with the ranking, we have *Empathy* (15%), *Fee* (9.7%) and *Responsiveness* (8%) (Chowdhary & Prakash, 2007).

A special effort to evaluate financial performances was spent by Ertugrul & Karakasoglu (2009): they evaluates the financial performances of 15 Turkish cement firms. The model was an AHP combined with TOPSIS, and included 18 different indicators, classified in 5 main categories. Here comes the list of these category, with the most important index belonging to that cluster, for the complete list please refer to Annexes: *Liquidity ratios (Cash ratio), Financial leverage ratios (Debt ratio), Activity ratios (Current assets turnover ratio), Profitability ratios (Net profit margin),* and *Growth ratios (Operating profit growth*) (Ertugrul & Karakasoglu, 2009).

5.5 FINDINGS AND CONCLUSIONS

As it happened in the analysis of the history of supplier selection, there are no common indexes to evaluate the candidates. This is due to the fact, underlined by Liu & Wang (2009), and Chen & Wu (2011), that the selection and evaluation of the indexes is strongly dependant on the decision makers' opinion. This point is noticeable also comparing Percin's (200) and Buyukozkan's (2009) works. In fact they used the same selection criteria, but they obtained two different results: for the first *market knowledge* and *performance* were the most important ones, while for the second one, *financial sustainability* and *sustainable relationships* were to be considered first.

Going through the researches related to service-supplier selection, the trend already discussed in the analysis of the history can be confirmed. In fact, as 3PL became a commodity, the focus of the selection was moved away from the mere price, with the most representative example given by Sonmez & Moorhouse (2010) that put *price* as the least important dimension.

On the other side, the driver of the choice is the experience and quality level of the supplier: *logistics information system*, *customer service* and *on time shipment* for Liu & Wang (2009); *logistic competences* for Bhatti, et al. (2010); *market knowledge* for Percin (2009); *capacity of service*, *knowledge* and *reputation* for Chang, et al. (2010); *operation performance* for Sharkharia (2007).

Another interesting trend that underlines again the dependency of the model on the subjective decision, is the growing importance in the latest works of dimensions related to the financial stability of the supplier: *vendor status* for Bhatti, et al. (2010), *financial stability* for Percin (2009) and Buyukozkan, et al. (2008) are only few examples. This fact can be understood referring to the specific context: the crisis of 2008 increased the importance of having healthy and stable suppliers.

The last point regarding service-supplier selection, is the growing attention on environmental dimensions: Efendigil (2008) and Lao, et al. (2011) put in the first positions criteria evaluation the environmental respect of the supplier, continuing the trend proposed by Humphreysa, et al. (2003) on the selection of "green" suppliers.

As regards the selection of suppliers for material purchasing, the focus of the decision process is slightly difference. In fact, in this specific context, price and quality are still the main drivers triggering the decision: *cost of ownership* for Chan, et al. (2008); *quality, delivery time and cost* for Koul, et al. (2011); *cost* for Chamodrakas, et al. (2010); *quality* and *price* for Kiluncci & Onal, Ting & Cho (2008), Demirtas & Ustun (2008) and Amin, et al. (2011).

A second minor trend is the attention of the strategic fit of the two companies: 3 authors (Huang & Keskar, 2007; Araz, et al. 2007; and Chou & Chang, 2008) focused their researches on the identification of selection criteria that can guarantee the correct alignment of supplier's and client's strategies.

The last point to underline is still the growing attention on "environmental respect": Yeh & Chang (2011), Bay & Sarkis (2010) and Shaw (2012) completely focused their works on the selection of the "greener" supplier among all the candidates.

B.2 ELECTRONIC INVOICING, INTEGRATION AND DEMATERIALIZATION

1. INTRODUCTION

A commercial invoice is the most important document exchanged between trading partners: it has not only a commercial value, but it has legal implications to both transacting parties and constitutes the basis for Value Added Tax (VAT) declaration, VAT reclamation, statistics declaration for intra community trade, and export and import declaration for extra community trade. Through a more systematic introduction of the e-invoicing, tax administrators may be able to implement new tools and procedures to carry out alternative controls that are less intrusive on the trading partners (Kaliontzoglou, et al., 2006). Nevertheless, e-invoicing can provide unprecedented visibility of the purchase-to-pay cycle and offer a range of financial and non-financial benefits to customers (Watkinson, 2010).

2. TRADITIONAL INVOICING PROCESS

As can be seen in Figure 14, Supply Chan Management is a broad concept that includes all the main activities and processes within the company.

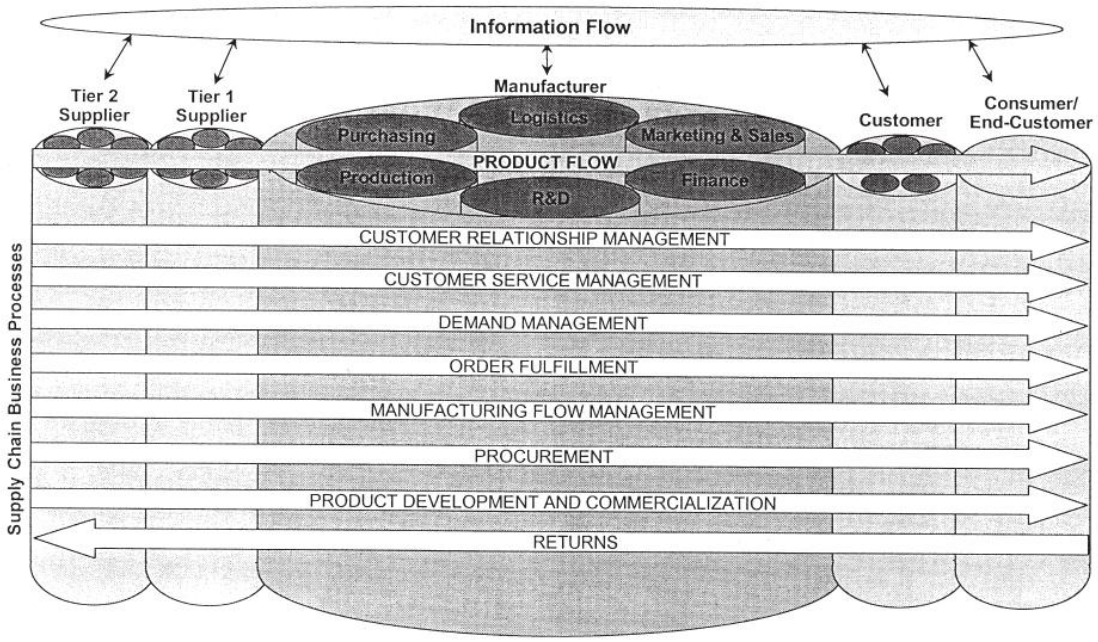


FIGURE 14 - PROCESSES INVOLVED IN THE SCM CONCEPT. *SOURCE: (LAMBERT & COOPER, 2000)*

The invoicing process is a fundamental part of this framework as it included and a wider set of business processes, such as the placing and acceptance of an order, its fulfillment, delivery and payment. This process can be seen with two focuses:

- From the buyer's perspective is the *purchase-to-pay process*;
- From the seller's perspective is the *order-to-cash process*.

An invoice can be defined as:

> A COMMERCIAL DOCUMENT USED BY BUYERS AND SELLERS OF GOODS AND SERVICES. IT HAS GROWN THROUGH CUSTOM AND PRACTICE BUT USUALLY IT HAS A NUMBER OF LEGAL REQUIREMENTS IMPOSED ON IT (NIENHUIS & BRYANT, 2010).

As underlined before, the emission of an invoice is not a standalone process, but it includes several other activities. An example of a trade process can be seen in the following figure.

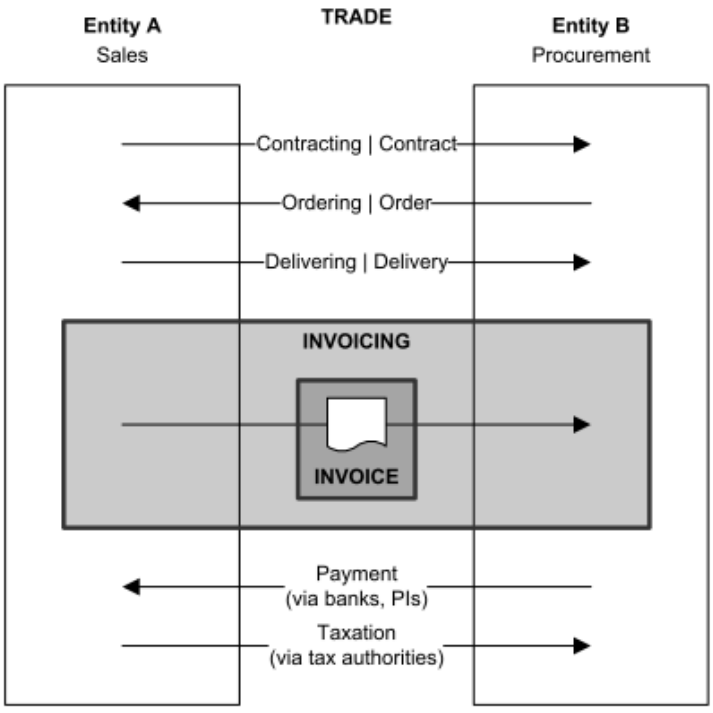


FIGURE 15 - TYPICAL TRADE PROCESS. *SOURCE: (NIENHUIS & BRYANT, 2010)*

The invoices produced as to be exchanged between seller and buyer. There are different methods to perform this exchange. The most common ones are mail and physical handover to the customer. Because there are many senders and receivers, the delivery of the invoices is a vast logistical operation based on the capability of the postal system.

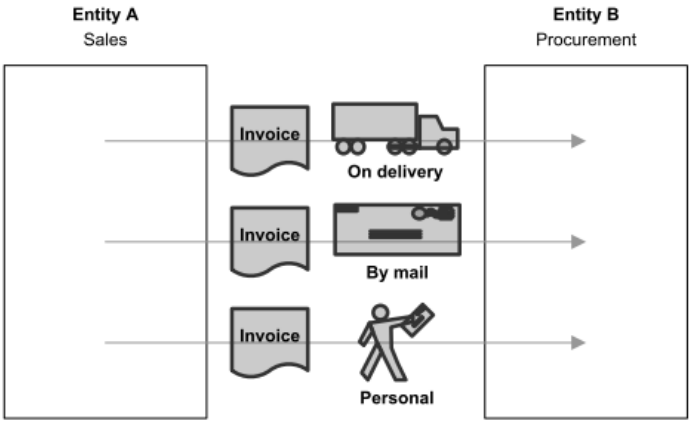


FIGURE 16 - DISTRIBUTION OF PHYSICAL INVOCIES. *SOURCE: (NIENHUIS & BRYANT, 2010)*

The main drawbacks identified in the European Report on E-Invoicing (2010) are (Nienhuis & Bryant, 2010):

- high operational costs for processing the invoice for both the sender and the receiver;
- protracted invoice-to-pay cycle time – a research by Celent showed that a complete purchase-to-pay cycle takes between 30 and 100 days;
- high costs for auditing and fraud prevention.

Furthermore, the extended usage of paper makes processes within the traditional supply chain inefficient, error prone and costly, with breakages that impede the flow of commercial and financial information. As a consequence, the key processes of the financial supply chain, such as accounts payable and receivable, are expensive to operate, leading to unfavorable payments terms and fail to deliver quality information to support decision (Schaefer, 2010).

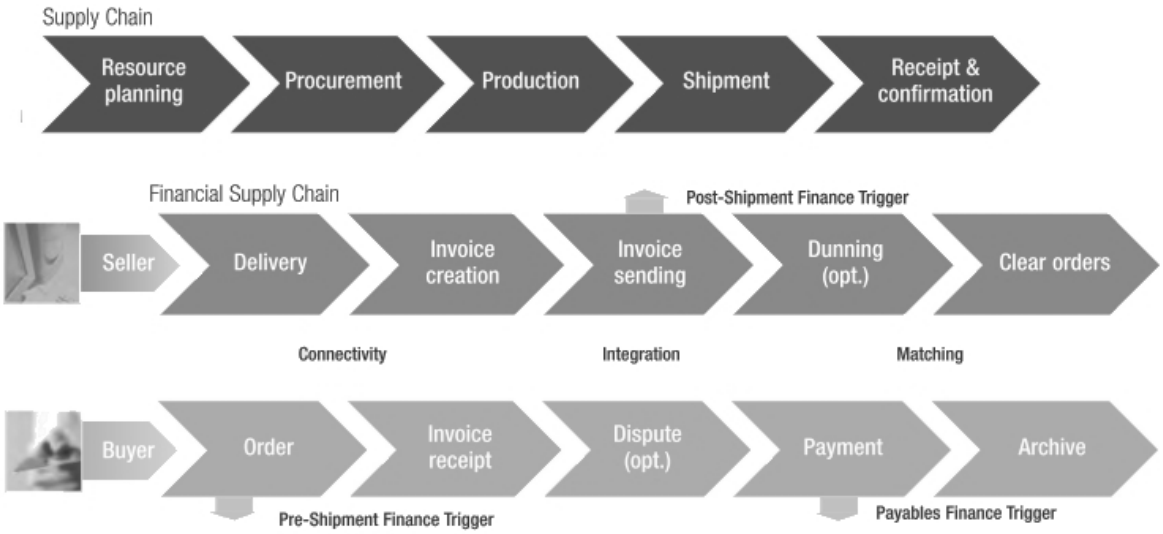


FIGURE 17 - THE FINANCIAL SUPPLY CHAIN IN A CORPORATE ENVIRONMENT. *SOURCE: (SCHAEFER, 2010)*

3. ELECTRONIC INVOICING AND DEMATERIALIZATION

The solution for the traditional invoicing drawbacks can be identified in the E-invoicing. In essence, electronic invoicing is the generic term given to web-based services that allow purchase orders and invoices to be issued, received, approved, reconciled and archived electronically (Watkinson, 2010).

The EU Council Directive 2001/115/EC of Dec 20th, 2001, provides a definition of e-invoicing and digital archiving:

> THE SENDING OF INVOICES 'BY ELECTRONIC MEANS', I.E. TRANSMISSION OR MAKING AVAILABLE TO THE RECEIVER AND STORAGE USING ELECTRONIC EQUIPMENT FOR PROCESSING (INCLUDING DIGITAL COMPRESSION) AND STORAGE OF DATA, AND EMPLOYING WIRES, RADIO TRANSMISSION, OPTICAL TECHNOLOGIES AND OTHER ELECTROMAGNETIC MEANS.

The e-invoicing document can be created in different forms:

- *unstructured invoice document* (e.g. Text, PDF, JPEG, TIFF, HTML or email) – in this case the document is created manually, and instead of printing it, the document is sent electronically to the receiver. An alternative is to digitalize the paper document by scanning it;
- *structured invoice document* (e.g. EDIFACT or XML) – in this case, the creation of the document consists of a compilation of the required data defined in the selected structure. The receiver will have to be familiar with the chosen format to be able to read it.

As the document is no more a physical one, the ways to deliver it changed from the traditional case, in particular the sender can use: emails, electronic presentment (for example the publication of the e-invoice on a website or an internet portal), or messaging protocols (this solution is used for structured messages and example can be HTTP, SMTP, AS2, SOAP and AMQP[25]) (Nienhuis & Bryant, 2010).

It has to be noticed that e-invoicing is not the finish line of the adaptation of electronic solutions inside business processes: further steps would be the integration into more parts of the financial and business value chains. This means moving from e-invoicing (with integrated e-payment) via e-procurement (with electronic catalogues and online ordering), e-trade (with integrated e-financing and digital trade papers) finally to a fully electronic real-time economy (Salmony & Harald, 2010).

[25] SOAP: Simple Object Access Protocol. AMQP: Advanced Message Queuing Protocol.

3.1 LEGAL FRAMEWORK

The European Union provides a uniform framework for the European market, under which e-invoicing is standardized and applicable in every European Member State. This harmonization effort is evident by the following directives (Kaliontzoglou, et al., 2006):

- Council Directive 2001/115/EC of 20 December 2001 amending Directive 77/338/EEC with a view to simplifying, modernising and harmonising the conditions laid down for invoicing in respect of value added tax.
- Council Directive 2006/112/EC of 28 November 2006 in the common system of value added tax[26] – This directive states that invoices sent or made available by electronic means shall be accepted by Member States provided that the authenticity of the origin and the integrity of their content satisfies the legal requirements (see following paragraphs). Member States may also ask for advanced electronic signature to be based on a qualified certificate and created by a secure-signature-creation device.

Apart from the general rules, an analysis of the specific Italian framework is more useful.

THE ITALIAN SITUATION

The e-invoicing process, in a broad sense, implies two concepts: the specific e-invoicing, and the digital archiving of the documents. Both these two issues are regulated by specific normative.

Regarding *e-invoicing*, the most important regulations are:

- *Decreto del Presidente della Repubblica 633/72*[27] – This decree includes different guidelines for the e-invoicing. First of all it imposes that the documents issued in an electronic format have to be managed in such way during the whole process, archiving included (Art. 39, terzo comma-DPR 633/72). Secondly it defines the need for the digital signature and the timestamp application on the document, and it allows the usage of EDI technology as one possible validation input; furthermore, the document cannot contain dynamic contents (Art. 21, terzo comma-DPR 633/21). Finally it defines that the emission date is not the one in which the document is created, by when the document is transmitted (Art.21, primo comma-DPR 633/72).

[26] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:347:0001:0118:en:PDF
[27] http://www3.unisi.it/ammin/uff-ragi/Fisco/DPR633-72.htm

- *Circolare 45/E del 10 ottobre 2005*[28] – this communication tackles the issue of the "15 days". In particular is clarifies that the electronic documents have to be archived at least every 15 days from its receipt.

As regards *digital archiving*, the regulations are:

- *Decreto del Ministro dell'Economia e delle Finanze del 23 gennaio 2004* [29]– This decree sets the main rules for the digital archiving. It first defines the documents available for the archiving (Art. 2, seconda comma[30]). It then defines some characteristics of the documents: static and not modifiable format, necessity to preserve readability during time and essential information to be included (Art. 3, primo comma, lettera d).
- *Risoluzione 220/E 13 agosto 2009* – This communication defines that, for some particular document, for example the ones produced and only available on paper, the digitalization has to be monitored by a "pubblico ufficiale".
- *Risoluzione 267/E 27 settembre 2007* – this communication defines in a clear way how the archiving should be done. In particular it underlines that the process can be different according to the document type, but the process selected must be equal for the same document type in order to guarantee the chronologic order.
- *Circolare 36/E 6 dicembre 2006* – This regulation allows the possibility to conserve of only part of the invoices and it provides some practical guidelines. Furthermore, the digitalization and conservation can be done at any time, for example at the end of the year, or digitalizing the old invoices.
- Other directives give other minor contributions. For example, they avoid the printing of the invoice (Risoluzione 158/E 15 giugno 2009), or impose the readability of the documents (Art. 2220, terzo comma – Codice civile) and the timestamp (Art. 6, primo comma – DMEF 23 gennaio 2004).

3.2 ELECTRONIC INVOICING SECURITY REQUIREMENTS

Given the high importance of the e-invoice document, the production and maintenance of it has to respect strict security requirements. Most of this requirements are imposed by Directive 2001/115/EC and the following Directive 2006/112/EC.

[28] http://www.interlex.it/testi/pdf/circ45e.pdf
[29] http://www.interlex.it/testi/pdf/dm040123.pdf
[30] "Il presente decreto non si applica alle scritture e ai documenti rilevanti ai fini delle disposizioni tributarie nel settore doganale, delle accise e delle imposte di consumo di competenza dell'Agenzia delle dogane." *(Art. 2, secondo comma – DMEF 23 gennaio 2004)*

- *Authentication of origin* – ensures that the sender is really the one who claims to be. This requirement can be satisfied by the application of XML digital signatures in combination with tamper resistant cryptographic modules such as smart cards. Furthermore, the use of Qualified Certificates may cover the corresponding requirement.
- *Integrity of the content* – the invoice must not be altered intentionally or accidentally during the transmission or storage. This integrity can be checked by a cryptographic hash function that can be included or not in the digital signature process.
- *Acceptance* – the customer should be able to decide whether to accept or decline e-invoicing by the supplier (Nienhuis & Bryant, 2010).
- *Confidentiality and privacy* – only the sender and the recipient can read the e-invoice. Confidentiality can be obtained by encryption.
- *Integrity of the sequence* – any gaps occurring in the outgoing invoices have to be avoided. This requirement is particularly important for tax authority control and can be satisfied by a sequence issuance scheme embedded in each invoice.
- *Availability* – companies or revenue services can be able to use an e-invoicing service at any time without disrupting their accounting practices. This implies that the system must be robust and protected by intrusion and hacking.
- *Electronic storage* –the EU Council Directive 2001/115 defines the requirement for the archiving in a secure and safe way. Authenticity of the origin, integrity of the content and readability must be granted throughout the storage period. The place of the storage can be any EU member state with online access to data (for extra EU states the European Data Protection principles must be respected) while period and format of the storage depend on the single Member State[31].
- *E-Invoicing application security policy* – an e-invoicing application should be accompanied by a corresponding policy, which would identify the signature policy (Kaliontzoglou, et al., 2006). The e-invoice should also include 10 mandatory items of information with the possibility of an additional 4 items in specific circumstances[32].

Strictly connected with the e-invoicing, there is the concept of *electronic signature*. The EU Council Directive 1999/93/EC[33] defines three forms of *electronic signature* listed below.

- *Basic electronic signature* – is the simplest and broadest sense of electronic signature as a means to identify and authenticate data (for example signing and e-mail with personal name). To be a signature, the authentication must relate to data. For example the putting a

[31] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:015:0024:0028:EN:PDF
[32] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:347:0001:0118:EN:PDF, Article 226
[33] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31999L0093:EN:HTML

sign through a PIN code on an e-mail is a signature, while entering a website with the same PIN is not a signature (there is no related document).

- *Advanced electronic signature* – this form has to meet the requirements defined in Article 2.2 of the Directive[34]. The Directive does not favour a particular technology, but in practice this definition refers mainly to electronic signatures based on a public key infrastructure (PKI). This technology uses encryption technology to sign data, which requires a pubic and a private key.
- *Qualified electronic signature* - this third form is mentioned in Article 5.1 of the Directive and consists of an advanced electronic signature based on a qualified certificate and created by a secure signature creation device (Europe's Information Society, 2011).

3.3 BENEFITS OF ELECTRONIC INVOICING

Before going through the main benefits deriving from e-invoicing, it has to be stated that e-invoicing is based on two fundamental principles (Observatory on Electronic Invoicing and Dematerialization, 2009):

1. *dematerialization* – that is the ability to eliminate paper document, transforming them in electronic documents; and
2. *integration of the processes* – that is the ability to improve the services of the trade process thanks to the direct exchange of electronic documents.

Having said this, e-invoicing has several demonstrated advantages. Here comes a list of the main ones.

- *Cost reduction* - Electronic and automated invoice processes can result in savings of 60-80% compared to traditional paper-based processing. Projects typically result in a payback period of 0.5-1.5 years. If electronic invoices replaced a major proportion of paper invoices, the saving potential in Europe‘s public sector could be at least 40 billion Euro (for inbound and outbound invoices). Today, less than 10% of it is exploited (Koch, 2012; Watkinson, 2010).
- *Quality and efficiency increase*- Huge potential of better resource allocation derived from the automation of low productivity manual processing; better systems integration can enhance an easier reconciliation of purchase and delivery; furthermore the reduction of manual data entry reduced significantly the possibility of errors.

[34] The “advanced electronic signature” has to: 1- be uniquely linked to the signatory; 2- Be capable of identifying the signatory; 3- be created using means that the signatory can maintain under his sole control; 4- to be linked to the data to which it relates in such a manner that any subsequent change of the data is detectable.

- *Better financial management* – a closer integration of the physical and financial supply chain gives rise to opportunities to better manage cash flow and liquidity. The benefit is not limited to the financial part, but also the management in general can rely on more accurate information (Watkinson, 2010).
- *Improved customer ser*vice – the use of electronic channels can increase flexibility and efficiency in the relation with the customer with a resultant increase in customer satisfaction (Nienhuis & Bryant, 2010).
- *Environmental savings* – it has been calculated that a 1% increased adoption of e-invoicing could lead to an annual reduction of tree usage of 800,000 trees. Furthermore, the adoption of e-commerce and e-paper solutions will enable a pollution saving of 100 $MtCO_2$ by 2020 (TheClimateGroup, 2008).
- *Risk reduction* – e-invoices can reduce risk as digital signature technology confirms the sender's identity and guarantees that the content has not been altered. In addition to that, e-invoicing can also eliminate error and bottlenecks and realizes the benefits of straight-through processing and automatic validation checks (Watkinson, 2010).
- *Global reach* – the virtual nature of the process eliminates geographical barriers and make the service available also to overseas partners (Watkinson, 2010).

4. ELECTRONIC INVOICING MODELS

Electronic invoicing is a term to describe a wide range of processes and solutions. Companies can, on one side, choose which processes to integrate with their suppliers and clients, and determine which "degree of dematerialization" they want to introduce. This first dimension leads to different "adoption paradigms": from the most simple ones (i.e. substitute archiving of invoices of unilateral document exchange) to the most complex ones (i.e. full integration and dematerialization of the trade process). Another dimension can be identified according to the fruition modes: companies can decide to develop these services internally (in house) or to rely on outsourcing.

4.1 DEFINITIONS

Before being able to describe what anticipated before, it's useful to clarify some definitions. In particular, the e-invoicing world is broad, and sometimes there is the problem of misunderstanding deriving from misinterpretations of the different services. In the following lines, I will set a basic line for the main services and solutions that will be tackled in this research.

DOCUMENT MANAGEMENT

Document Management is used to identify a set of integrated solutions to manage the digital information, in a structured and non-structured way, aiming at support individual productivity, process optimization, collaboration and general support to company's strategy. "Electronic document management systems focus on facilitating the management of documents pertinent to particular enterprises, projects and work groups in computer networks.". (Bjork, 2002)

DIGITAL ARCHIVING[35]

Digital Archiving is the process through which accounting documents – invoicing received and issued, Accounting Books and records – can be stored in a digital way with a full substitution of the hard copies for legal matters. The process differs according to the type of document considered. The common point is the need to put digital signature and timestamp on the documents by the responsible if the digital archiving named by the company (Observatory on Electronic Invoicing and Dematerialization, 2012).

ELECTRONIC INVOICING[36]

The "pure" e-invoicing model (called "A norma di legge"), assumes that there is a written agreement between the sender and the receiver to regulate the process. The document has to be issued, transmitted, received and archived in digital form. On the e-invoice, the sender has to put its digital signature and the timestamp to guarantee authenticity and integrity. A particular attention has to be put on the 15-day issue: as a consequence of the written agreement, the two companies have to archive the invoices in a maximum of 15 days. This is the one of the main problem linked to the "pure" e-invoicing.

The number of companies that have implemented the "pure" invoicing is still limited. There are though, a higher number of companies that have adopted the "QUASI e-invoicing". This is a term used by the Observatory on Electronic Invoicing and Dematerialization to indicate the adoption of the e-invoicing process without the official written agreement between the actors. This solution enables the companies to exploit the advantages deriving from the e-invoice, without having the limitation imposed by the regulations (Observatory on Electronic Invoicing and Dematerialization, 2012).

[35] These considerations are valid for the Italian framework
[36] These considerations are valid for the Italian framework

4.2 ADOPTION PARADIGMS

As can be seen in Figure 18, e-invoicing in the broad sense (integration and dematerialization of the trade process) can have significant implications in the trade process:

- integration and collaboration between organizations,
- horizontal integration between the phases of the trade process, and
- vertical integration between interfaces activities (Observatory on Electronic Invoicing and Dematerialization, 2008).

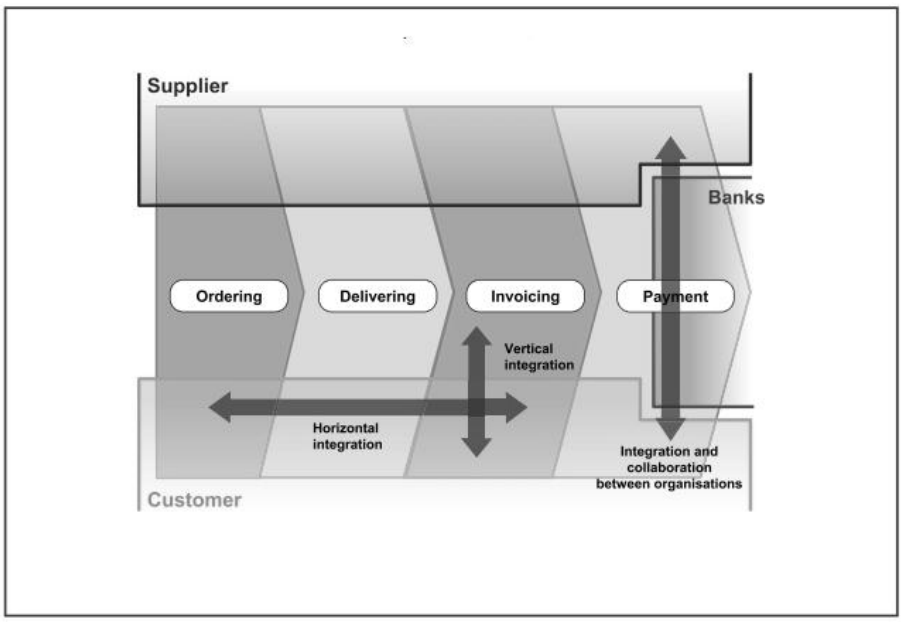


FIGURE 18 - E-INVOICING IN THE TRADE PROCESS. *SOURCE: (OBSERVATORY ON ELECTRONIC INVOICING AND DEMATERIALIZATION, 2008)*

With reference to this framework, different adoption paradigms can be identified. These paradigms differ both in relation to the process coverage (or the company area impacted) and on the emphasis placed on dematerialization and integration principles. These two dimensions influence in a relevant manner the potential benefits obtained by the e-invoicing process.

Several adoption paradigms were identified by the Observatory on Electronic Invoicing and Dematerialization (2008); for sace of syntesis, in the following paragraph I will present only the main three ones (Observatory on Electronic Invoicing and Dematerialization, 2010).

SUBSTITUTE ARCHIVING

In this paradigms the two companies (or even only one of those), electronically storage invoices issued to clients (“digitalization of the active”) and/or the invoices received by the suppliers (“digitalization of the passive”).

The main benefits are linked to the reduction of space and transmission time and are quantifiable in 1 ÷ 2 €/cycle for the storage of the receivable and 0.5 ÷ 1.2 €/cycle for the digitalization and storage of payables. In this particular case there is no guarantee (i.e. there is no agreement between the actors) that the transmission of the invoices is done electronically.

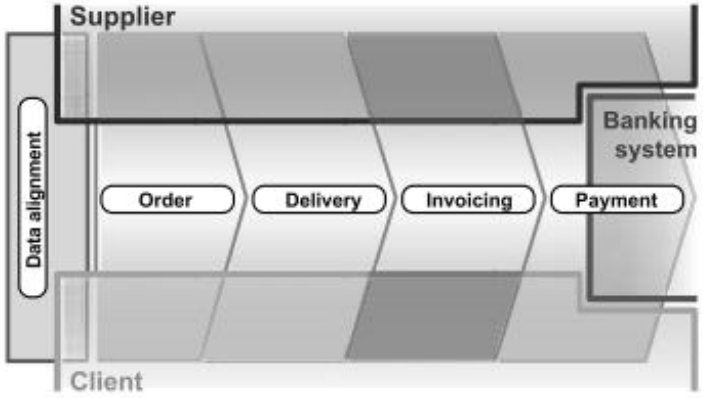


FIGURE 19- SUBSTITUTE ARCHIVING ADOPTION PARADIGM. *SOURCE: (OBSERVATORY ON ELECTRONIC INVOICING AND DEMATERIALIZATION, 2010)*

ELECTRONIC INVOICING (PURE SENSE)

In this solution there is an agreement between trade partners for the exchange of invoices generated, transmitted and stored in electronic format. These invoices can be in unstructured format (i.e. image files not directly modifiable) or structured format (i.e. the data contained can be directly modified by computer applications). In case of structured e-invoicing the benefits are linked to an increase productivity and are quantifiable in 5.5 ÷ 8.5 €/ cycle, while in case of unstructured documents the benefits are 1.8 ÷ 4 €/cycle and derive from space optimization and faster transmission.

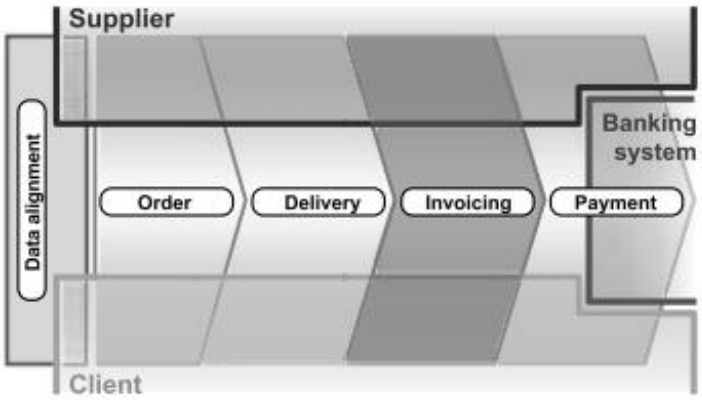


FIGURE 20 - ELECTRONIC INVOICING ADOPTION PARADIGM. *SOURCE: (OBSERVATORY ON ELECTRONIC INVOICING AND DEMATERIALIZATION, 2010)*

This case assumes that all the documents exchanged between customers and suppliers are in electronic format. Within this paradigm, three main solutions are possible. The first one is the integration of the order-invoice cycle: the documents exchanged from the logistics-commercial cycle are fully dematerialized and integrated, from the issuing of the order to the generation of the invoice. The second one Is the integration of the invoice-payment cycle: all the documents belonging to the administrative-financial cycle are dematerialized, from the receipt of the invoice to the payment of it (this solutions includes the banks). The last one is a full integration and dematerialization of the order-payment cycle: from the issuing of the order to the payment (note that this solution includes collaboration with both supplier and banks).

As easily predictable, this solution offer a great improvement in the productivity, leading to an economic saving of 25 ÷ 65 €/cycle.

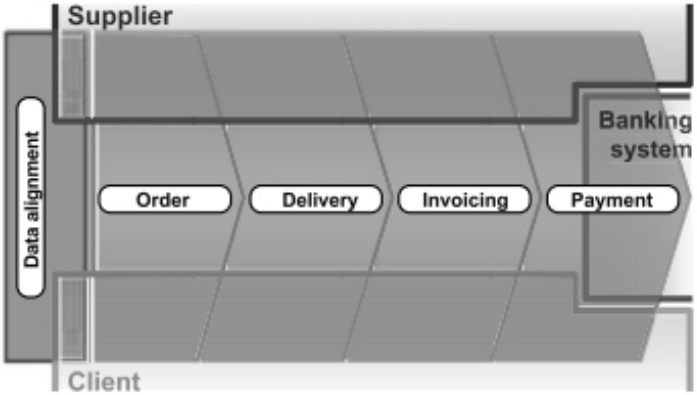


FIGURE 21 - FULL INTEGRATION ADOPTION PARADIGM. *SOURCE: (OBSERVATORY ON ELECTRONIC INVOICING AND DEMATERIALIZATION, 2010)*

4.3 SERVICE FRUITION MODES

The second dimension determining the e-invoicing models is linked to how the company decides to perform those solutions. The adoption paradigm can be implemented on the basis of different types of technology and of process control (called “service fruition modes”). Three main alternatives as follows.

- *In house* – the company decides to implement internally the process, acquiring the hardware and the software needed, or developing a customized solution. This solution guarantees a strong control on the documents, mainly in terms of privacy.
- *Application Service Provider (ASP)* – the company decides to rely on an external player for the technological solution (even if some of the hardware may still be needed internally), but to keep internal supervision of the process.

- *Outsourcing* – the company fully relies on an external operator, outsourcing the whole process (Observatory on Electronic Invoicing and Dematerialization, 2010).

5. ELECTRONIC INVOICING MARKET

The possibility to use e-invoicing and substitute archiving offered by the law has incremented the interest of many companies and actors on this new and evolving market. The result is a new configuration in the offer-demand equilibrium and the birth of new players.

5.1 MARKET PLAYERS

The e-invoicing world is characterized by several different players. A first classification of these entities is linked to the e-invoicing process: in a common invoicing practise, an electronic transaction occurs between the issuer for the invoice and the receiver; during the transaction, though, other players are involved.

- *The issuer* – this organization hosts the e-invoicing service infrastructure. It takes the appropriate steps to deploy the service and publish it in the registries, so that the organizations may find it. It also communicates with the Trusted Third Party (TTP) to get the proper security credentials.
- *The receiver* – the receiver organization, who receives the e-invoice, may be part of the same architecture, or may operate a completely independent e-invoicing service. The receiver has to communicate to the TTP to get the security credentials.
- *The Trusted Third Party (TTP)* – the role of the TTP is to establish an adequate security framework between all the participants. Examples of TTPs can be Certification Authorities (CA) and Registration Authorities (RA) offering the Public Key Infrastructure (PKI) service of registration, certification and revocation status information, as well as a Time Stamping Authority (TSA) offering standard based time stamping services.
- *The UDDI directory operator* – this operator hosts a public Universal Description Discovery and Integration (UDDI) directory where Web Services can be published and thus become available (Kaliontzoglou, et al., 2006; Karantjias, et al., 2007).

A second classification, more linked to the nature of the players, was proposed in the 2008 report by Observatory on Electronic Invoicing and Dematerialization, that identified a growing trend between the actors, both in terms of number and categories. Here come the results.

- *Corporate world* – business sectors or supply chain association that hopes that these new solutions will provide the sufficient critical mass not achieved by the EDI, but at the same time fear that they might have to accept choices imposed by authorities or banks.
- *Banking sector* – the bank world, after having invested significant money in internal integration (inter-bank networks), offers to supply new external integration services (between banks and companies) to the corporate world.
- *Public sector authorities* – authorities see electronic invoicing as a fundamental step towards dematerialization and transparency, as long as a tool to generate valued for the country.
- *Technology and service providers* – these are providers that see a good chance to mainstream a series of solution that have been seen complex and costly until few years ago.
- *Professionals* – all the professionals involved in this process, from the company managers to the IT, finance, administration and sales, that see a possibility to extend their skills, but are also threat by a significant change in their own roles (Observatory on Electronic Invoicing and Dematerialization, 2008).

5.2 SUPPLY MARKET

The Observatory on Electronic Invoicing and Dematerialization (2008) identified 3 main players in the supply market. The list follows after Figure 22.

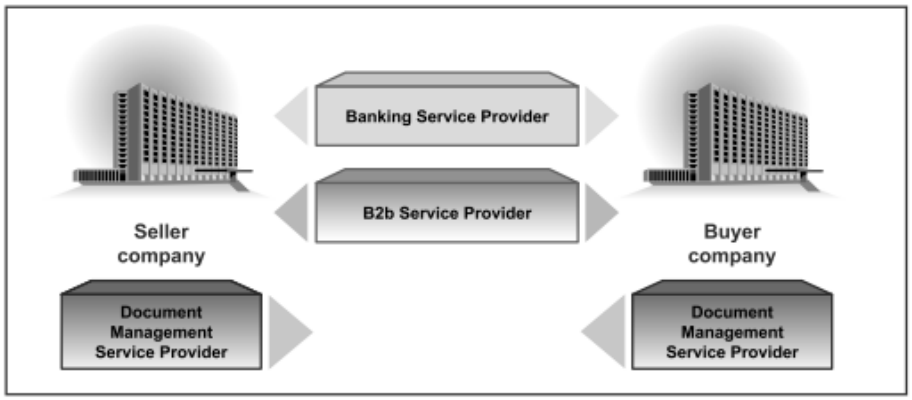


FIGURE 22 - THE SUPPLY WORLD. *SOURCE: (OBSERVATORY ON ELECTRONIC INVOICING AND DEMATERIALIZATION, 2008)*

- *B2b Service Providers (or Integration Service Providers)* – these are operators specialized in solutions for structured exchange of order cycle documents and the automation of the supply chain processes.
- *Banking Service Providers* – thanks to the new CBI 2[37] functionalities, banks are now able to provide advanced solutions to manage the administrative-financial cycle.

[37] The Customer to Business Interaction is a service that enables companies to work directly with all the banks adopting CBI through the usage of a personal computer and the Internet.

- *Document Management Service Providers* – this category includes all the suppliers of solution to manage structured and non-structured documents, as well as the providers of document management services and the systems integrators (Observatory on Electronic Invoicing and Dematerialization, 2008).

6. ADOPTION BARRIERS

Even though e-invoicing and dematerialization can offer several advantages and consistent cost savings, the choice to adopt and implement such functionalities has still to face different barriers.

The Observatory on Electronic Invoicing and Dematerialization (2010) classified the main barriers in 5 main categories:

1. the need to invest in change management;
2. the poor understanding of obtainable benefits;
3. the perception of lack of clarity of the laws;
4. the fear that the necessary costs or investments will be excessive;
5. the awareness of not possessing the necessary competences.

The most relevant one among these five is perceived to be the need to invest money and time and the change management process, in particular with an internal focus. The second most important is the poor understanding of the benefits tied to dematerialization; it has to be stated though, that many companies do not even try to calculate the benefits, so this issue is easy to overcome. Similar considerations can be done with the calculation of the investment costs and operative costs. The last issue to be perceived as a barrier is the lack of clarity in the norms: companies perceive that norms are not clear and are too complex, while the regulatory framework is in constant evolution.

The barriers of adoption change depend also on the adoption paradigm adopted (Observatory on Electronic Invoicing and Dematerialization, 2010):

- for the e-invoicing (in a strict sense) projects, the main problem is the evaluation of the costs associated to the investment, as this type of project is considered to be medium-long term, with little relevance in the short term;
- as regards the integration of the order-payment cycle the main barrier is the poor perception of the benefits associated to the project, supported by the fact that this kind of project requires more investments that the other two.

7. CONCLUSIONS

As emerged from this few pages, e-invoicing is a relatively new world that Governments are regulating (even if not in a complete way) and companies are exploring. This process is included in a wider context, called dematerialization, that can include different configuration and can lead to consistent cost savings. The basic idea is the simple dematerialization of the invoice, reducing the time needed for the transmission and the possibility of transcription/reading errors. It is easily predictable that the cost savings linked to this solution are limited. On the other side though, significant cost reductions can be obtained with a full integration of the dematerialization process, starting from the digital acquisition of the order, through the electronic transmission of the invoice, until the automatic payment of the bill. The benefits are not only limited to a faster process, but also quality, efficiency and transparency of it increases a lot.

Even though these benefits are evident and demonstrated, companies are still reluctant to adopt these solutions, mainly because of the necessity to invest in the change management. In order to foster the adoption, central Governments are trying to set a common legal framework that can be used as a baseline to guarantee consistency and compatibility of the singular solutions. In addition to this, other initiatives are being put in place from the different Member States (for example the necessity of adopting e-invoicing for exchanges with the Public Administration put in place by the Italian Government).

What is evident is the born of new actors inside the market and the evolution of the offering of the already existing ones: new comers, like specialized e-invoicing companies, are now competing with banks and software houses that have developed dematerialization solutions. Even the services offered are getting more and more complex, trying to include all the potential dematerialization aspects of the business: from a simple dematerialization of the invoices, to the digital archiving, ending with the document management and integration of the whole value chain.

C. OBJECTIVES AND METHODOLOGY

In this paragraph I will explain the objectives pursued in developing this research as long as the methodology that I followed. The main purpose of this thesis is to determine which are the most important aspects to evaluate when selecting a supplier of electronic invoicing and digital archiving services.

The research will derive from two main contributions: the first one is the direct consequence of the literature review on supplier selection, with the objective to select the most used selection criteria, and the second one derives from my personal analysis of the supply market, in order to better understand the current situation and decide the applicability of the indexes selected.

The criteria identified will then be weighted using a specific model that I will derive applying the AHP methodology to this specific content.

1. OBJECTIVES

The recent changes in the marketplace that are pushing towards more effective and efficient ways of running the everyday business activities, and the attempt from the Governments to favor a more transparent and green economy, has encouraged the implementation of electronic solutions in the invoicing process.

The literature on provider selection is huge, but the main drawback is that the majority of the attention was spent for supplier selection in a material purchasing context, and few works were related to service provider selection. Furthermore, within this already limited number of researches, no efforts have been spent on selecting the best supplier of e-invoicing and digital archiving sector.

For this reason, companies are now in the condition of having to select one supplier among several possible ones, with no clear differences between their offerings or absolutely no previous experience in this field. Furthermore, this decision is even more complex given the relevance and importance of the data considered: invoices, bills, purchasing orders, employees' salaries, financials are very important and reserved data that, in case of wrong usage, can lead a company to failure or serious problems.

> THE OBJECTIVE OF THIS RESEARCH IS TO IDENTIFY AND EVALUATE WHICH ARE THE MOST IMPORTANT CRITERIA TO BE CONSIDERED WHEN SELECTING A SUPPLIER FOR ELECTRONIC INVOICING AND DIGITAL ARCHIVING SERVICES.

To do this, an innovative model will be developed. The model will be based on the application of the AHP methodology combined with a Total Cost approach: the first method will be applied to the general characteristics of the company, while the second one will be used to calculate the cost of the solution. In this way, the decision maker will be able to compare the possible suppliers not only with reference to one single cumulative index, but could perform a trade-off analysis between performances and costs.

Both the evaluations will be based on a set of indexes derived from the literature and from a set of interviews, and then validated by experts. The model developed will be a useful tool that decision makers can use to have solid basis for the final decision on which supplier to select, filling up the gap identified in the literature.

2. FRAMEWORK

In order to provide a comprehensive view and solid model, the initial analysis was divided in two streams. The following points describe the structure of the work.

- *Analysis of the literature* – The first part is the analysis of the literature and the knowledge available. This part is divided in two sub sections:
  - One dedicated to the supplier selection problem. The objective is to derive the most-used selection criteria divided according to a temporal framework, sector of application and selection method used. This part contains also a brief explanation of the selection methods and an evaluation of the most used ones.
  - The second section is the analysis of e-invoicing and digital archiving processes. This part includes also an overview on the Italian legislations, the adoption barriers and the utilization models. The purpose of this analysis is to provide useful information about the subject of the research, the legal requirement and the different aspects to be included.
- *Analysis of the market* - The second one is the analysis of the supply market. This research has been done through a series of interviews to the principal actors of the market, in order to better understand the composition of the companies and the service offered. The purpose of this second stream is to provide a basis for the final selection of the indexes for the specific case of this thesis.

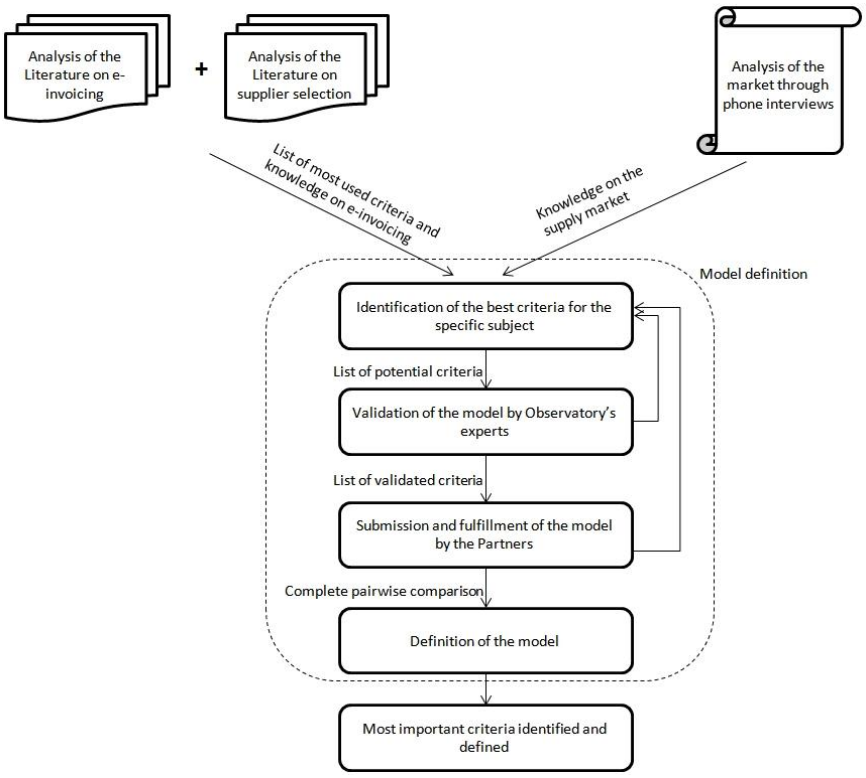


FIGURE 23 - DEVELOPMENT FRAMEWORK

After this first part, the development of the model began. The result of the first contribution was a set of indexes ranked according to their popularity. The following step was, exploiting the knowledge accumulated thanks to the second stream, to select the most useful criteria among the available ones. Then, the selected indexes where submit to the experts of the Observatory on E-invoicing and Dematerialization of the Politecnico di Milano for a first validation.

When the complete list has been derived, I developed the comparisons needed for the determination of the weights and I submitted the questionnaire to the partners of the Observatory. Notice that this step is a further validation of the indexes by other experts and actors of the market. Once the questionnaires were sent back, in was able to derive the weight for each criteria based on the comparisons.

Thanks to the results deriving from the development of the model, the most important factors for the supplier selection has been identified, defined and the model is ready for being used by decision makers.

2.1 ANALYSIS OF THE LITERATURE

The first research stream is the analysis of the literature. As already said before, this part is divided in two subparts: supplier selection and dematerialization.

2.1.1 SUPPLIER SELECTION

This is the thickest part in terms of number of papers in works included. The methodology used is described in the following 3 points.

1. First research and evaluation of the papers found on the supplier selection problem. The scope of this first point was to select which one could be relevant for this thesis and which not.
2. The works identified as useful have been carefully analyzed, taking note of the criteria used, the context of application and the selection method used.
3. The single contributions were then classified and prepared for the analysis in the Literature review.

The number of papers analyzed, and the number of criteria identified were:

Number of papers for the first step	99
Number of useful papers	40
Total number of criteria	703

The 40 useful papers were timely distributed as follows:

Year	1966	1989	1990	2002	2006	2007	2008	2009	2010	2011
# papers	1	1	1	1	1	4	7	9	9	6

As regards the journals:

Journal	**Number of papers**
Applied Mathematical Modelling	1
Automation in Construction	1
Benchmarking: An international Journal	1
Computers & Industrial Engineering	2
Computers & Operations Research	1
Expert Systems with Applications	13
IEEE	1
IEEE Computer Society	1
Information & Management	1
International Journal of Computational Intelligence Systems	1
International Journal of Electronic Business Management	1
International Journal of Production Economics	3
International Journal of Production Research	2
Journal of Manufacturing Technology Management	1
Journal of Modelling in Management	1
Journal of Purchasing	1
Journal of Purchasing and Material Management	2
Journal of Supply Chain Management	2
Management Decision	2
Omega: The International Journal of Management Science	2
Supply Chain Management: An international journal	1
Total	**40**

In order to evaluate the relevance of the paper, the impact factor of the paper was considered. Here follows the specifications of the impact factors. To provide a complete evaluation, the impact factors were considered in the specific year in which the work was published. Note that the sum of the impact factors is lower than the number of journals, this is due to the fact that for some journals, especially the oldest ones, it were not possible to find the it.

For an obvious reason, the different values of the impact factors have been divided in 6 groups.

Impact Factor	0 – 0.5	0.5 - 1	1 – 1.5	1.5 - 2	2 – 2.5	2.5 – 3
# papers	0	3	6	5	5	2

2.1.2 ELECTRONIC INVOICING AND DIGITAL ARCHIVING

The analysis of this second part of the literature review has been relatively shorter: this issue is quite new and the attention of the scholars on this topic is not yet very high. The main contributions were derived from the researches done by the Observatory on Electronic Invoicing and Dematerialization of the Politecnico di Milano, and the European Market guides developped by Nienhuis & Bryant, 2010 and Koch 2012.

2.2 ANALYSIS OF THE MARKET

The second stream from which my analysis derives, is a set of interviews done to the different service suppliers present in the market (in total 26 interviews). These interviews were aiming at the comprehension of the business model pursued by the company, the value proposition, the different services offered and how do they configure. A second purpose was to better understand the dimension and composition of their clients to estimate the diffusion of dematerialization practices.

2.2.1 STRUCTURE OF THE INTERVIEWS

In order to guarantee homogeneity between all the interviews, a general baseline has to be defined. For this reason an interview structure was created. Even though this format exists, the interviews were not managed in a static way, but the interviewer tried to let the other person talk, trying to catch all the most interesting aspects and keeping an informal atmosphere. The structure was then used to check if all the issues have been tackled[38]. These issues are listed below.

- *Business data* – general information on the company, such as some history, area of origin and revenues in order to dimension and classify the different interviews' subjects.
- *Client* – this part was referred to understand the typology and the number of clients that the company has, as long as the sector in which they operates. This part was aimed at better clarify the demand side of the market and estimate its evolution over time.
- *Services* – this is the central part: it tackles the specific services offered by the company, their dimension and percentage on the total revenues, their future evolution and the fruition models that they offer. The aim of this part was to understand and classify the offering, with reference to the type of company being interviewed.
- *Technological infrastructure* – this limited section was focused on the internal technology available within the supplier, trying to understand the investment that a company had to sustain in order to offer these kinds of services. The time needed for the investment was considered too.

[38] The complete format can be find in Annexes

- *Client management* – after having defined the offering and the clients' typology, a deeper analysis on the clients' management was needed. In particular this section aimed at understand the types of documents managed by the company and, if possible, their percentage on the total, the pricing logic that they offer to their clients and their marketing strategy to get to the clients.
- *Internal composition* – the last part of the interviews was used to better understand the internal composition of the supplier, determining the percentage of commercials versus technicians as long as the number of employees allocated to these kinds of services.

2.2.2 NUMBER, TIMING AND COMPANIES

The interviews have been performed from October 2011 and March 2012 in the context of the Observatory on Electronic Invoicing and Dematerialization in Politecnico di Milano.

The total number of interviews is:

- 19 full structured interviews: for these companies no past data were available, so the interview was a full analysis of that actors, following the previous schema;
- 7 updating interviews: for these companies past data were available. In particular this means that the previous year a structured and deep interview has already been performed. The aim of this analysis was to depict any changes from the previous year and understand the evolution of the company/market[39].

The composition of the interviews is as follows (note that the classification is based on the sector of origin and on the main focus of the company's activity):

Type	Number		Description
	Full	Update	
Banks	2		Banks that have enlarged their offering with dematerialization services.
Certification authority	1		Companies that has received the authorization from the government to relies certifications.
EDI	4		Companies that have as the core business the offering of EDI services.
Postal	1		Companies offering postal services as core business.
Services	11	2	This kind of companies acts like service providers, offering dematerialization services as core business.
Printers		2	Companies born as printing companies.
Software		3	Companies which the main focus are the development of the

[39] The structure of the interview was pretty the same as the full one, with a lower attention on the general data and an higher focus on the evolution.

house			software.
Total	**19**	**7**	

2.3 MODEL DEFINITION

The principal tool to meet the research objective is the original model that I create. This specific model allows deriving a ranking of the different selection criteria selected.

In the literature review I've identified several selection methods to rank the selection criteria: Analytic Hierarchy Process, Analytic Network Process, Total Based Cost Approaches, Delphi method, Case Based Reasoning and Technique for order preference by similarity to the ideal solution (TOPSIS), also combined with the usage of fuzzy numbers.

2.3.1 SELECTION OF THE EVALUATION METHOD

Each of the different selection methods have strengths and weaknesses already described in the literature review. For the specific case of this thesis I can make the following personal considerations.

- *Total Based Cost Approach* – the dematerialization services considered in this selection process are very critical and any malfunctioning can cause serious problems to the company. For this reason an evaluation based only on costs can be strongly reductive.
- *Delphi method* – this method is based on a discussion between stakeholders and experts in order to get to a shared solution. Since the experts on the supply-market side are mainly working at a high level in their companies, it's hard to expect from them and active participation that would require a lot of time.
- *Case Based Reasoning* – Since there are no previous examples of supplier selection for this type of services, this method cannot be applied.
- *TOPSIS* – the lank of previous experiences and data in this field makes the definition of the best solution very difficult.
- *ANP* – this method is potentially useful, but it requires more time to the stakeholders (they also have to define the relationships among the criteria) to compile the comparison. Since the stakeholders have limited time, this method cannot be used. Furthermore, since the valuation is at a high level, the independencies of the criteria can be easily guaranteed.

For these reasons, the best selection criteria for my model is the *Analytic Hierarchy Process*: it is quite simple to use, both for stakeholders and users, the methodology is mature and strengths and weaknesses are clearly defined. Furthermore, this is the most used criteria among the previous works.

During the development of the model I noticed that a more interesting result could be achieved dividing the cost indexes from the other ones: this would allow a double comparison of the suppliers, one on the general performances and the other one on the cost of the solution. Furthermore, this kind of representation allows other subjective considerations, such as "Is the difference in cost worth referring to the performances?", "Is the high price motivated by outstanding performances?".
For this reason, the structure of the model will be:

- AHP for *Business, Solution*, *Capabilities* and *Green & Environment* dimensions;
- Total Cost for *Cost* indexes.

2.3.2 STEPS FOR DEFINING THE MODEL

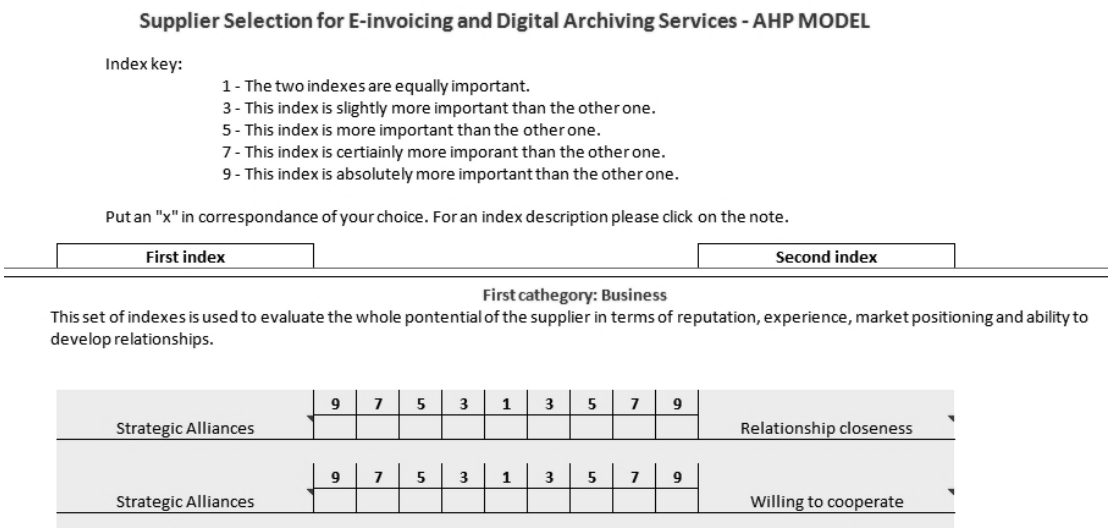
The steps followed during the model development are as follows.

1. *Identification of the indexes* – this steps is particularly complex because it includes the analysis of all the 703 indexes derived from the literature review and the definition of the common ones. In fact, different authors may have used different names to indicate the same criteria, or, on the other hand, the same criteria to indicate different aspects. The output of this process is the definition of 83 different criteria divided in 24 categories.
2. *Selection of the indexes* – it can be easily noticed that 83 indexes are too much for my model. Furthermore some of them are not completely related to this specific case (for example the "Logistics" category). For this reason, a selection has to be performed. The tools to select the indexes are: first of all an evaluation of the relevance of the index based on the original indexes that it includes, this part is made more solid by a sensitivity analysis on the weights used during the evaluation. Then, the criteria remained have been individually validated, thanks to the knowledge created during the market analysis and the literature review, in order to select the most appropriate for the specific case[40]. The final step is the validation of the indexes identified performed by the experts of the Observatory on Electronic Invoicing and Dematerialization of the Politecnico di Milano.
3. *Pairwise comparison and weights definition* – the AHP model is based on a pairwise comparison between the indexes belonging to each category. This third step is the definition of the comparison made by the principal market players selected among the partners of the Observatory. Once comparison is done, the weights can be derived and the model defined.

[40] A more detailed explanation can be found in the specific Model chapter.

2.3.3 QUESTIONNAIRE FOR THE PAIRWISE COMPARISON

The model assumes a comparison between each criteria belonging to the same category in order to define which is more important, and how much, between the two. To obtain this evaluation, a questionnaire was sent to the principal market players. A screenshot of the Excel file can be seen below (the whole file is available as Annexes).



Supplier Selection for E-invoicing and Digital Archiving Services - AHP MODEL

Index key:

1 - The two indexes are equally important.
3 - This index is slightly more important than the other one.
5 - This index is more important than the other one.
7 - This index is certiainly more imporant than the other one.
9 - This index is absolutely more important than the other one.

Put an "x" in correspondance of your choice. For an index description please click on the note.

First index										Second index

First cathegory: Business

This set of indexes is used to evaluate the whole pontential of the supplier in terms of reputation, experience, market positioning and ability to develop relationships.

	9	7	5	3	1	3	5	7	9	
Strategic Alliances										Relationship closeness
	9	7	5	3	1	3	5	7	9	
Strategic Alliances										Willing to cooperate

FIGURE 24 - EXAMPLE OF THE QUESTIONNAIRE FOR THE COMPARISON

Once the questionnaires have been received, they have to be combined to get a unique solution. In order to do this, I followed the steps listed below.

1. For each single questionnaire, I applied the AHP model and derived the weights.
2. Then, in order to decide which one to include in the final model, I calculated the Consistency Ratio[41]. This ratio is useful to measure the correctness of the comparisons. In fact, Saaty (1980) stated that, for a matrix 3x3 the CR shouldn't be higher than 5%, 8% for a 4x4 matrix and 10% for bigger ones. The questionnaires that did not respect these conditions were eliminated.
3. Finally, a new matrix, with the evaluations calculated as the average of the consistent ones, has been defied, the weights derived, and the Consistency Ratio re-computed (Saaty, 1980).

[41] This index is derived calculating the ratio between the Consistency Index (that derives from the average values of the product between the comparison matrix and the weights columns) and a Random Index defined by Saaty (1980).

3. THE MODEL

The first purpose of this model is to identify the most important selection criteria for the specific context of this thesis. Furthermore, this model is developed in order to provide the decision maker with a solid basis on which to build its decision: it will highlight the performances of potential suppliers under different aspects and will provide a useful comparison of the actors involved.

Once the indexes are identified and ranked, the user just has to fill in the value of the criteria, following the directives described in the model chapter, and will receive an overall evaluation of the potential suppliers. In particular, the model will explicit an overall rank, specified in 4 main categories: *Business, Solution*, *Green and environment*, and *Capabilities*. This rank will then be compared with the costs of the solution derived calculating the total cost (the dimensions to be considered in the total cost evaluation are listed in the model part).

This model is particularly useful for the initial screening and evaluation of the suppliers, passing from a relatively high number of potential companies to a very limited one. The final decision will then have to be taken by the decision maker based on its personal experience and other subjective evaluations.

The services to which this model refers are e-invoicing and digital archiving. It has to be noticed, though, that many companies offer other services, such as document management or EDI, in addition to these basic ones. For this reason, the selection will be based on e-invoicing and digital archiving services, but the actual purchase of the decision maker may include other services.

D. ANALYSIS OF THE MARKET

This chapter contains the analysis of the market. The literature review is useful to provide a comprehensive view of what has been done up to now. But it also have some limitations: first of all, for this specific case, the strictly connected works are few, secondly it is based on researches that are referred to previous years, or, in an optimistic view, to the beginning of 2012 (the time to approve the article and publish it is also to be considered). For this reason, a direct and empirical analysis of the market could have been useful.

This market analysis is made on a series of phone interviews to different actors to the marketplace, in order to evaluate the actual development situation and have complete and updated view of the problem.

1. INTRODUCTION

The analysis of the Literature can contribute with some knowledge on the issue in general terms and with concrete past examples. In this case, given the high specificity of the research and the relatively recent changes in the marketplace, a direct analysis of the market can be useful.

For this reason, a set of interviews was made at the beginning of the year (2012) in order to better understand the composition of the supply market, the configurations of the offerings and the maturity level of the clients.

A total of 26 companies, divided into service companies, banks, EDI providers, printers, certification authorities and postal companies were interviewed. In this section I will present the key findings derived from the elaboration of those interviews, for a more detailed description of the methodology adopted, please refer to the methodology chapter.

2. KEY FINDINGS

This set of interviews depicted several interest and particular aspects of the supply market. The following paragraphs will not specify which company is offering what, but will provide a general overview on different relevant aspects of the supply market.

2.1 SERVICES OFFERED

Electronic invoicing and digital archiving are not two standalone services, but are linked to a set of additional ones. As easily predictable from the scope of the interviews, digital archiving is the predominant service among all the actors: all the banks, certification authorities, printers and postal offer this kind of solution, while regarding the services world, digital archiving is proposed by the 54% of the actors either in a direct way or through partners. Document management is the second most popular service offered, with the 43% of the service companies, 50% of banks and all printers and certification authorities proposing it. Electronic invoicing is another predominant service, but the different negative aspects already stated are limiting its implementation: only half of the banks and of the EDI companies offers these kind of solution, the percentage decreases again if referring to service companies (39%). It has to be noticed also, that the majority of the companies not offering e-invoices services declared that the reason is that clients don't ask for those solutions, but they are willing to implement them as soon as the market is ready.

The possibility to exploit web EDI allowed non-EDI companies to offer this kind of service: 11% of the service companies include web-EDI solutions in their offering. Here are listed other popular services.

- *Channeling* – this service consists in the delivery of the invoices (but also other documents) done by the company on behalf of its client. This delivery can be done in different ways: in a digital form, by sending an email with the invoice attached, posting it on a website, or sending it through EDI, and in a paper form, sending the hard copy of the document.
- *Digitalization* – through this solution the company retrieves the paper copies and digitalizes them on behalf of its clients. The digital copies are then sending back to the client. The benefit of this service is that the client don't have to lose time in a repetitive and non-value adding activity.
- *Delivery of the archive track*[42] – using this service the supplier is taking the responsibility to send the archive track to the Agenzia delle Entrate. This service is relatively new and companies are beginning to offer it.

In addition to these transversal services there are other solutions offered only by some typology of actors.

- *Certificates release* – this service included the emission of the certificates to ensure the authenticity of the sender in case of e-invoicing and digital archiving. Due to the its specificity, this service is mainly limited to Certification Authorities, with only few service companies (4%) that have invested to provide it.
- *Integration with banks* – adopting this kind of solution, the company can completely automate the order-payment side of the invoicing process. As underlined in the literature review, this step is fundamental for the full integration. This type of integration is the one offering the highest advantages in terms of costs saving, but it's very limited. The configuration of the supply market follows the same pattern: only the 4% of the service companies include this service and it remains a prerogative of banks.
- *Integration with the suppliers* – the same reasoning can be done considering the upper side of the supply chain: the integration with the other actors of the supply chain can provide significant cost savings, but it's not exploited: only 11% of the service companies offer a solution to integrate the invoicing process inside the supply chain.

In general the interviews have underlined the tendency of the actors to enlarge their offering, trying to increase the sources of revenues. This trend is also visible when referring to the future

[42] The Italian legistation in 2010 ("Provvedimento del Direttore dell'Agenzia delle Entrate 25 Ottobre 2010") imposed the delivery to the authorities of a record of the digital archive. The scope of this communication is to univocally identify the archive and to guarantee that it will be frozen and not modified in the following years until the time limit set for the conservation. The sending can be done by the responsible for the digital archiving or by an authorized third person ("Art. 5, comma 2 Centro nazionale per l'Informatica nella Pubblica Amministrazione (Cnipa) 19 Febbraio 2004, n. 11"). The communication must include the identification data of the sender, the conservation place, the list of the included documents and the time stamp ("Art. 3, comma 2-bis e 3, DPR 22 Luglio 1998, n.332).

development seek by the companies: the attempt to apply dematerialization solutions to "whatever can be dematerialized" and the attention towards new trends such as new digital signing solutions (for example the "firma grafometrica").

Another consideration to be done is that e-invoicing and digital archiving solutions are quite standard, for this reason companies has to propose supplementary and innovative services in order to differentiate their offering among the competitors.

2.2 EVOLUTION OF USERS AND CLIENTS

On the supply side, when talking about banks, postal, printers, certification authorities and EDI providers, it's trivial to underline that e-invoicing and digital archiving services derive from an evolution and enlargement of the already existing offering. More interesting considerations can be done when referring to the service companies: the majority of them are companies specialized in document management (29%), followed by software houses (18%). The 25% of the service companies are, instead, new born realities that started their business with e-invoicing and digital archiving solutions.

On the clients' side, we have two different trends when adopting dematerialization solution equally distributed among the adopters. The first one is to start from the already adopted document management system and include dematerialization solutions to it. The second one consists in the implementation of the digital archiving process (the most easy and fast to be implemented) for the invoices issued, usually in a limited part of the company. This first step provides a first break of the habits within the company, facilitating the change management and the implementation of more pervasive solutions.

2.3 TYPOLOGY OF THE CLIENTS

The distribution of the clients reflects the higher attention of the big realties to implement e-invoicing and digital archiving processes: the volumes are significant, the investment is more affordable and the potential cost savings are not negligible. The interviews highlighted that the 70% of the clients of the certification authorities are big companies, while the remaining 30% is equally split between medium and small ones. The percentage is in favor of the big companies also for the postal's clients (63%). As regards the clients of the services companies the distribution is the same between big and medium enterprises (40%), with the remaining 20% of small ones. A predominance of medium enterprises is, on the other hand, depicted by banks and printers (55% for banks and 70% for printers).

As regards the client's sectors, the market is in favor of insurance and big distribution sectors: 30 % of the companies declared to have at least one client belonging to this sector. The other companies are quite widespread among the different industries: automotive (that dominates the EDI companies' clients), healthcare, and public sector (as a consequence of the government's restrictions analyzed in the literature).

2.4 PRICING LOGICS

One of the main objectives of the interviews was to understand the pricing policies applied by the suppliers to their clients. The research highlights a common pattern adopted by the majority of the operators. In fact, except for some limited companies that try to differentiate their offering proposing a full-fixed or full-variable price, the cost of the service is divided in 3 dimensions:

- a startup cost, this is what the company has to pay for the installation and customization of the solution;
- a fixed annual price, usually dependent on the volumes for the initial amount, but then fixed during the collaboration;
- a variable price, in the order of some euro cent, that the company has to pay according to the actual documents managed. This price is usually function of the average volumes of documents of the company.

3 CONCLUSIONS

What emerged from the interviews is a continuous diversification of the offerings: electronic invoicing and digital archiving are not 2 standalone services, but are strictly connected to a series of other functionalities. This phenomenon is originated from two main reasons. The first one is the fact that e-invoicing and digital archiving alone cannot provide the sufficient revenues for a company to survive, except for some suppliers with particularly big clients. For this reason the market players try to exploit those kind of services to penetrate in the organization's structure and provide more value added (and source of revenues) services: document management, dematerialization of "whatever can be dematerialized", PEC, integrated payments and Web EDI.

The second reason is the attempt, made from the suppliers, to differentiate their offering adding more value added services, considering that e-invoicing and digital archiving are difficult to differentiate.

Even the analysis of the habits of the clients underlined the evolution of this sector: the demand market is not stable nor mature, but it's characterized by an increasing number of clients that are

trying to introduce electronic solutions in their business in order to save money and be able to reply in time to the requests deriving from the Government. The introduction of these kinds of services is not easy: there are several adoption barriers to be faced. For this reason companies are usually willing to introduce step by step the solution, starting from an already existing service and enlarging it, or using pilot projects.

As regards the clients' typology, the demand market is characterized by medium-big enterprises that are more aware of the economic benefit deriving from big volumes. Also the pricing is in favor of big companies, with frequent, and natural, volume discounts, together with startup costs and fixed rates.

In general, suppliers are trying to enhance the potentialities deriving from e-invoicing and digital archiving solutions, providing both general and very focused solutions, selecting flexible pricing logics and exploiting client's fidelity.

E. THE MODEL

In this section I will develop my original model.

This model will be bases mainly on the Analytic Hierarchy Process, method that allows ranking and giving a weight to a limited set of attributes. The baseline of this model is the pairwise comparison of a set of criteria divided in a tree-structure. As regards the cost indexes a Total Cost approach will be applied.

The indexes derived from the literature will first be evaluated with reference to the specific case, and then the best ones will be selected. A group of experts belonging to the Observatory on E-Invoicing and Dematerialization of the Politecnico di Milano will validate them. Several market players will then be asked to provide the comparisons between the criteria, and the model will be derived.

1. INTRODUCTION AND FRAMEWORK

As already said before, this is the first path to define the supplier selection model. In particular, in this paragraph I will present an initial classification of the indexed found in the literature. The complexity of the work is linked to the necessity of reducing and finding a common line of thinking among 703 indexes expressed by 40 different authors.

The main five first-level categories identified are the followings.

- **Business**: information regarding the company in a general sense, with focus on issues such as culture, compatibility and risk.
- **Capabilities**: performances and abilities of the potential supplier, in terms of financial solidity, managerial and operational capacity.
- **Solution**: evaluation of the products or services proposed by the supplier in a global and comprehensive way.
- **Green & Environment**: definition of the "green" level of the company and its attention toward sustainability.
- **Cost:** evaluation of all the costs occurring during and after the purchasing process.

The following pages will contain the indexes clustered according to the specific category. All these indexes are presented inside a table. The content of these tables is presented below.

- **Category**: is the category to which the paper belongs to. The categories are for:
  - *Material (M):* includes all the papers that analyzed the supplier selection problem in a material purchasing context.
  - *Service (S):* the focus of that paper is the supplier selection for a service.
  - *General (G):* the paper has no particular focus, but it analyzed the problem in a general way.
  - *Old (O):* this category includes all the papers written before 2002. The idea behind this category is that, first, if the indexes identified were worth, some authors had for sure used them in a more recent work, and second that is difficult to compare old indexes with the modern ones because the impact factors is very difficult to find and may have been calculated in a different way.
- **Authors**: the authors that used the specific index.
- **Impact factor**: the impact factors used to evaluate the relevance of the particular journal in which the paper was published. Note that the paper under the category "old" has no impact factor.
- **Original criterion**: the criterion proposed by the author.

- **Criterion defined**: the criterion in which all the single indexes can be include.
- **Description**: brief description of the criterion defined.

The results are 84 different third-level indexes, clustered in 24 second-level categories, divided in 5 first-level dimensions.

2. INDEXES DEFINITION

2.1 BUSINESS

General information regarding the company. Including data with an internal focus, with attention on the internal culture, organization and experience, an external focus, with attention to the positioning inside the competitive market, the different partnerships and its reputation, and an overview of the risks associated to the market and the company itself.

Compatibility – it measures the level of compatibility between potential supplier and customer. The compatibility is evaluated under three main dimensions: cultural, strategic and organizational.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
S	Percin, 2009	1.86	Compatible culture	**Cultural fit**	Compatibility of the two actors' culture.
M	Chan, et al. 2008	2.596	Cultural similarity		
M	Lee, 2009	2.908	Incompatibility between buyer and supplier		
S	Liu & Wang, 2009	2.908	Cultural fit		
G	Tan, et al. 2008	2.205	Cultural compatibility		
S	Buyukozkan, et al. 2008	2.026	Compatible culture		
S	Das & Buddress, 2007	1.583	Company culture		
S	Percin, 2009	1.86	Similar size	**Organizational fit**	Similarities of the two companies in terms of dimension and internal structure.
G	Bai & Sarkis, 2010	1.988	Compatibility among levels and functions		
S	Buyukozkan, et al. 2008	2.026	Similar size		
S	Das & Buddress, 2007	1.583	Legacy systems		
S	Das & Buddress, 2007	1.583	Existing processes		
S	Das & Buddress, 2007	1.583	User skills		
S	Das & Buddress, 2007	1.583	Data protocol of existing supply chain members		
S	Das & Buddress, 2007	1.583	Ease of migration path		

S	Percin, 2009	1.86	Similar values-goals	**Strategic fit**	Alignment between the two companies' objective, values and goals.
M	Chou & Chang, 2008	2.596	Strategic fit		
G	Bai & Sarkis, 2010	1.988	Strategic fit		
G	Bai & Sarkis, 2010	1.988	Top management compatibility		
S	Buyukozkan, et al. 2008	2.026	Similar values-goals		
O	Ellram 1990		Strategic fit		
S	Das & Buddress, 2007	1.583	Strategic fit		

Experience – category measuring the experience of the potential supplier. The experience is expressed considering the general market knowledge, the recorder previous experiences that the supplier can provide and any specific experiences linked to a specific industry, market or company.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
S	Percin, 2009	1.86	Market knowledge	**Market knowledge**	General knowledge of the market, given by, for example, the time spent in the business. Note that this is a general evaluation of the experience of the supplier not referred to any specific industry.
S	Amin & Razmi, 2009	2.908	Experience		
M	Chan, et al. 2008	2.596	Supplier representative's competence		
S	Sun, et al. 2010		Operating experience		
M	Aydin & Kahraman, 2010	1.471	Experience and performance		
S	Buyukozkan, et al. 2008	2.026	Market knowledge		
S	Sonmez & Moorhouse, 2010	1.302	Time in Business		
M	Lam, et al. 2010	1.311	Past record	**Previous experiences**	Recorded examples of past experiences of the supplier, both in a global sense, and with respect to the any specific previous cooperation with the customer.
G	Razmi, et al. 2009	1.491	Company's antecedents		
M	Onut, et al. 2009	2.908	References		
S	Das & Buddress, 2007	1.583	Customer references		
S	Sonmez & Moorhouse, 2010	1.302	References		
S	Sonmez & Moorhouse, 2010	1.302	Clients		
M	Vinodh, et al. 2011	2.203	Diversified customers		
G	Tan, et al. 2008	2.205	History (past relationships)		
S	Chang, et al. 2010	2.627	Previous cooperation with proprietors		
S	Chen & Wu, 2011	0.8	Accumulating experience		

O	Dickson 1966		Performance history		
O	Dickson 1966		Amount of past business		
S	Sonmez & Moorhouse, 2010	1.302	Demonstrated good knowledge		
S	Sonmez & Moorhouse, 2010	1.302	Offer real experience		
S	Sonmez & Moorhouse, 2010	1.302	Projects completed		
S	Sonmez & Moorhouse, 2010	1.302	Personal assessment		
M	Amin & Razmin, 2011	2.203	International communication	**Specific experiences**	Experience related to a specific product, industry or sector of the potential supplier.
S	Liu & Wang, 2009	2.908	Experience in the similar industry		
S	Chang, et al. 2010	2.627	Knowledge on the clients' industry		
M	Sevkli, et al. 2007	0.56	Patent		
S	Das & Buddress, 2007	1.583	Industry experience		
S	Sonmez & Moorhouse, 2010	1.302	Intellectual property		
S	Sonmez & Moorhouse, 2010	1.302	Knowledge of industry		
S	Sonmez & Moorhouse, 2010	1.302	Publications		
S	Sonmez & Moorhouse, 2010	1.302	Qualifications of trainers		
S	Sonmez & Moorhouse, 2010	1.302	Successful stories		
S	Jharkharia & Shankar, 2007	1.327	Experience in similar products		

General information – Generic information regarding the company, its culture and attitudes, its dimension and location. In addition, information regarding the market in which the company operates are included.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Chan, et al. 2008	2.596	Positive attitude towards complaints	**Attitudes**	Demonstrated attitudes and practices adopted by the company. Example can be the desire for business or the ability to change thinking.
S	Liu & Wang, 2009	2.908	Continuous improvement		
G	Bai & Sarkis, 2010	1.988	Management attitude for the future		
O	Dickson 1966		Attitude		
O	Dickson 1966		Desire for business		
O	Muralidharan, et al. 2002		Attitude to improve operations		
S	Sonmez & Moorhouse, 2010	1.302	Ability to change thinking		

S	Sonmez & Moorhouse, 2010	1.302	Demonstrate cultural understanding		
M	Ebrahimnejad, et al. 2011	1.579	Company objective and policy	**Culture**	Organizational culture, in terms of goals and values.
M	Chan, et al. 2008	2.596	Ethical standards		
G	Tan, et al. 2008	2.205	Societal consciousness		
S	Chang, et al. 2010	2.627	Enterprise culture		
G	Tan, et al. 2008	2.205	Company size	**Dimension**	Size of the potential supplier.
S	Sonmez & Moorhouse, 2010	1.302	Size		
M	Ebrahimnejad, et al. 2011	1.579	Governmental regulation/standard	**Environment characteristics**	Characteristics of the geographical location in which the company operates, in terms of local welfare and specific regulations.
M	Chan, et al. 2008	2.596	GDP growth rate		
M	Ebrahimnejad, et al. 2011	1.579	Geographical location	**Location**	Geographical positioning of the potential supplier. It can include an evaluation also on the distance between supplier and customer.
M	Amin & Razmin, 2011	2.203	Geographical location		
M	Chan, et al. 2008	2.596	Geographical location		
M	Kilincci & Onal, 2011	2.203	Geographical location		
S	Liu & Wang, 2009	2.908	Location		
G	Tan, et al. 2008	2.205	Proximity		
M	Aydin & Kahraman, 2010	1.471	Geographical location		
S	Chen & Wu, 2011	0.8	Fitness of geographical location		
M	Sevkli, et al. 2007	0.56	Geographical location		
M	Yang & Chen, 2006	0.65	Distance		
O	Dickson 1966		Geographical location		

Internal organization & practices – considerations of the internal composition of the supplier. In this category, information regarding the internal organization and the employee's composition are included, as long as the evaluation of the main managerial and employment practices. A focus on the quality systems is considered too.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Bai & Sarkis, 2010	1.988	Discrimination	**Employee composition**	Composition of the internal workforce, in
G	Bai & Sarkis, 2010	1.988	Diversity		

M	Sevkli, et al. 2007	0.56	Number of employees		terms of number of employees, as long as gender composition or cultural diversity.
M	Ebrahimnejad, et al. 2011	1.579	Resource requirement		
M	Ebrahimnejad, et al. 2011	1.579	Staffing		
M	Araz, et al. 2007	1.147	Ratio of graduates		
S	Chang, et al. 2010	2.627	Capacity of employees		
S	Chen & Wu, 2011	0.8	Employee performance		
M	Chan, et al. 2008	0.774	Labour skill		
O	Dickson 1966		Labour relations records		
S	Das & Buddress, 2007	1.583	Key employee turnover		
O	Muralidharan, et al. 2002		Technical manpower availability		
S	Sonmez & Moorhouse, 2010	1.302	Language		
S	Sonmez & Moorhouse, 2010	1.302	Personnel		
G	Liou & Chuang, 2010	1.924	Knowledge skills		
M	Sevkli, et al. 2007	0.56	Number of technical staff		
G	Bai & Sarkis, 2010	1.988	Career development	**Employment practices**	Adopted practices to manage employee's relationships. Example of common practices can be training, career development paths and flexible working arrangements.
G	Bai & Sarkis, 2010	1.988	Employee contracts		
G	Bai & Sarkis, 2010	1.988	Employment compensation		
G	Bai & Sarkis, 2010	1.988	Equity labor sources		
G	Bai & Sarkis, 2010	1.988	Flexible working arrangements		
G	Bai & Sarkis, 2010	1.988	Health and safety practices		
G	Bai & Sarkis, 2010	1.988	Job opportunities		
M	Sevkli, et al. 2007	0.56	Training		
G	Bai & Sarkis, 2010	1.988	Disciplinary and security practices		
G	Bai & Sarkis, 2010	1.988	Health and safety incidents		
S	Jharkharia & Shankar, 2007	1.327	Employee satisfaction level		
M	Ebrahimnejad, et al. 2011	1.579	Project-identification	**Managerial practices**	Series of practices and methods adopted by the management. Example can be the presence or not of a performance
M	Sevkli, et al. 2007	0.56	Cost analysis		
O	Muralidharan, et al. 2002		Inspection method		
S	Jharkharia & Shankar, 2007	1.327	Performance measurement		
M	Kilincci & Onal, 2011	2.203	Working with Kanban approach		

S	Das & Buddress, 2007	1.583	Service record		measurement system or the inspection method adopted.
O	Muralidharan, et al. 2002		Following TQM, JIT practices		
S	Buyukozkan, et al. 2008	2.026	Successful track record		
M	Kilincci & Onal, 2011	2.203	Management	**Organizational Structure**	Internal structure of the potential supplier.
M	Vinodh, et al. 2011	2.203	Supplier profile		
G	Bai & Sarkis, 2010	1.988	Suppliers organizational structure and personnel		
M	Sevkli, et al. 2007	0.56	Organizational structure		
S	Sonmez & Moorhouse, 2010	1.302	Presentation		
M	Araz, et al. 2007	1.147	Quality certificates	**Quality system**	Presence or not of a quality system. Further indexes can regard any possible quality certificates, the quality philosophy or the quality assurance techniques.
M	Araz, et al. 2007	1.147	Quality controls		
S	Amin & Razmi, 2009	2.908	Security		
M	Chamodrakas, et al. 2010	1.924	Rejection Rate from quality control		
M	Chamodrakas, et al. 2010	1.924	Remedy for quality problems		
M	Chan, et al. 2008	2.596	Quality assessment technique		
M	Kilincci & Onal, 2011	2.203	Quality systems		
M	Lee, 2009	2.908	Quality systems		
M	Lee, 2009	2.908	Yield rate		
M	Vinodh, et al. 2011	2.203	Commitment to quality		
M	Aydin & Kahraman, 2010	1.471	Quality assurance certification		
G	Bai & Sarkis, 2010	1.988	Quality philosophy		
M	Sevkli, et al. 2007	0.56	Inspection		
M	Ting & Cho, 2008	2.341	Quality system		
G	Tan, et al. 2008	2.205	Site evaluation		
M	Sevkli, et al. 2007	0.56	Management commitment		
M	Sevkli, et al. 2007	0.56	Quality assurance		
M	Sevkli, et al. 2007	0.56	Quality planning		
G	Tan, et al. 2008	2.205	Quality infrastructure		

Market position – positioning of the company inside the competitive market. The two dimensions considered are the company's rank and the volumes of business achieved.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Razmi, et al. 2009	1.491	Company's rank	**Company's rank**	Ranking of the company among the direct competitors within the local market or in a global view.
S	Bhatti, et al. 2009		Global Market ranking		
S	Bhatti, et al. 2009		Local market ranking		
S	Liu & Wang, 2009	2.908	Market share	**Volume of business**	Market share of the company, operational boundaries and geographical spread to evaluate the volume of the company's business referred to the global market.
S	Sun, et al. 2010		Volume of Business		
S	Bhatti, et al. 2009		Operational boundaries		
S	Bhatti, et al. 2009		Scale of operations		
S	Das & Buddress, 2007	1.583	Market share		
S	Jharkharia & Shankar, 2007	1.327	Market share		
S	Jharkharia & Shankar, 2007	1.327	Geographic spread and access to retailers		

Partnership programs – considerations on the relationships between the potential supplier and its clients. The strategic alliances already in place, the level and quality of these relationships, as long as the willingness to set up new cooperation, are included in this category.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lee, 2009	2.908	Joint product/technology development	**Eagerness to cooperate**	How much the company is willing to set new relationships. Measured, for example, as the time required for setting a new relationship, or as the willingness of the supplier to participate to customer's operations.
S	Chen & Wu, 2011	0.8	Developing long-term relationship		
G	Bai & Sarkis, 2010	1.988	Partnership formation time		
S	Jharkharia & Shankar, 2007	1.327	Willingness to use logistics manpower		
M	Ting & Cho, 2008	2.341	Co-design production		
M	Amin & Razmin, 2011	2.203	Mutual trust	**Relationship closeness**	How tight the actual relationships are. It considers the frequency of the communications between the actors as
M	Chan, et al. 2008	2.596	Communication openness		
M	Chan, et al. 2008	2.596	Regular communications		

M	Lee, 2009	2.908	Closeness of relationship		long as which are the processes shared.
M	Lee, 2009	2.908	Complementarity of capabilities		
M	Lee, 2009	2.908	Ease of communication		
G	Liou & Chuang, 2010	1.924	Information sharing		
M	Vinodh, et al. 2011	2.203	Sharing of experience		
G	Tan, et al. 2008	2.205	Level of trust		
G	Bai & Sarkis, 2010	1.988	Feeling of trust		
G	Bai & Sarkis, 2010	1.988	Communication openness		
G	Bai & Sarkis, 2010	1.988	Relationship closeness		
O	Dickson 1966		Reciprocal arrangements		
O	Ellram 1990		Feeling of trust		
S	Das & Buddress, 2007	1.583	Trust		
O	Muralidharan, et al. 2002		Cooperation scheme		
S	Sonmez & Moorhouse, 2010	1.302	Personal contact		
S	Jharkharia & Shankar, 2007	1.327	Information sharing		
M	Demirtas & Ustun, 2008	2.175	Mutual trust & ease of communication		
M	Demirtas & Ustun, 2008	2.175	Support to design process		
M	Lam, et al. 2010	1.311	Buyer supplier relationship	**Strategic alliances**	Strategic alliances, partnerships and memberships that the company has at time now, or that had in the past and can guarantee with recorded data.
S	Percin, 2009	1.86	Strategic partnerships		
S	Amin & Razmi, 2009	2.908	Strategic alliances		
M	Lee, 2009	2.908	Stabilized relationship		
G	Liou & Chuang, 2010	1.924	Relationship		
G	Bai & Sarkis, 2010	1.988	Long term relationship		
S	Buyukozkan, et al. 2008	2.026	Sustainable relationship		
S	Sonmez & Moorhouse, 2010	1.302	Membership		
S	Sonmez & Moorhouse, 2010	1.302	Personal relationship		
S	Sonmez & Moorhouse, 2010	1.302	Successful relationships		

Reputation – reputation of the company, including any possible references deriving from previous cooperation and from customer loyalty data, as long as the general reputation of the industry in which the company operates in.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
S	Efendigil, et al. 2008	1.057	Customer Satisfaction index	**Customer loyalty**	Satisfaction level and rejection rate of past and current customers.
M	Chou & Chang, 2008	2.596	Customer rejection rate		
G	Liou & Chuang, 2010	1.924	Customer satisfaction		
M	Lam, et al. 2010	1.311	Reputation	**General reputation**	General perception of supplier's honesty, believability and reliability within the business.
M	Chan, et al. 2008	2.596	Market reputation		
M	Chan, et al. 2008	2.596	Supplier's believability and honesty		
M	Lee, 2009	2.908	Bad performance history and reputation		
S	Liu & Wang, 2009	2.908	General reputation		
S	Chang, et al. 2010	2.627	Reputation		
M	Aydin & Kahraman, 2010	1.471	Reputation		
G	Bai & Sarkis, 2010	1.988	Reputation for integrity		
S	Sonmez & Moorhouse, 2010	1.302	Recommend		
M	Sevkli, et al. 2007	0.56	Reputation		
O	Dickson 1966		Reputation and position in industry		
O	Muralidharan, et al. 2002		Honesty		
M	Vinodh, et al. 2011	2.203	Reputation of industry	**Industry reputation**	General reputation of the industry in which the supplier operates in.
S	Chen & Wu, 2011	0.8	Industry reputation		

Risk – evaluation of the risk associated with the company and the environment. The internal risk is considered including managerial stability, operational risk and economic status.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Razmi, et al. 2009	1.491	Company's Economic status	**Economic status**	General evaluation of the economic status of the company. Note that this is just a general consideration, as a more specific evaluation is included in the financial performances.
M	Lee, 2009	2.908	Financial risk		
G	Tan, et al. 2008	2.205	Economic stability		
M	Chan, et al. 2008	2.596	Corruption perception	**Environment risks**	Risks and issues related with the geographical location in which the company operates in.
M	Chan, et al. 2008	2.596	Currency stability		
M	Chan, et al. 2008	2.596	Exchange rates and economic position		
M	Chan, et al. 2008	2.596	Political and economic stability		
M	Chan, et al. 2008	2.596	Political stability and foreign policies		
M	Chan, et al. 2008	2.596	Terrorist and crime rate		
M	Lee, 2009	2.908	Supplier's raw material acquisition difficulties		
M	Lee, 2009	2.908	Variation in price		
G	Liou & Chuang, 2010	1.924	Labour union		
M	Araz, et al. 2007	1.147	Reliability	**Management stability**	Stability of the management at the top level of the organization in order to guarantee constant commitment with the client.
S	Amin & Razmi, 2009	2.908	Management stability		
M	Amin & Razmin, 2011	2.203	Management stability		
S	Percin, 2009	1.86	Complexity in operations and delivery	**Operational risks**	Risks related to the normal operations of the supplier. For example the security level of the internal communication systems, or of the internal data sharing system. Any past case of lawsuits or problems with previous clients can be considered too.
M	Chan, et al. 2008	2.596	Legal claims		
G	Liou & Chuang, 2010	1.924	Information security		
M	Vinodh, et al. 2011	2.203	Buyer supplier constraint		
M	Vinodh, et al. 2011	2.203	Supply constrains		
S	Sun, et al. 2010		Data security		
S	Sun, et al. 2010		Information accuracy		
S	Sun, et al. 2010		Staffing level		
S	Chang, et al. 2010	2.627	Lawsuits with clients		
S	Chang, et al. 2010	2.627	Maintenance of business confidentiality		
S	Das & Buddress, 2007	1.583	Range of variability of outcomes		

S	Das & Buddress, 2007	1.583	Possibility of catastrophic loss		
M	Demirtas & Ustun, 2008	2.175	Customer complaints		
M	Demirtas & Ustun, 2008	2.175	Order delays		
M	Demirtas & Ustun, 2008	2.175	Unavailability to meet further requirements		

2.2 CAPABILITIES

Macro category evaluating the capabilities and performances of the supplier under different dimensions, such as financials, operational and managerial ones.

Financials – indexes considering the financial status of the supplier under a detailed way.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Ertugrul & Karakasoglu, 2009	2.908	Account payable turnover ratio	**Activity ratios**	Ability of the firm to convert different accounts within the balance sheets into cash or sales.
G	Ertugrul & Karakasoglu, 2009	2.908	Account receivables ratio		
G	Ertugrul & Karakasoglu, 2009	2.908	Current assets turnover ratio		
G	Ertugrul & Karakasoglu, 2009	2.908	Inventory turnover ratio		
G	Ertugrul & Karakasoglu, 2009	2.908	Total asset turnover ratio		
G	Ertugrul & Karakasoglu, 2009	2.908	Debt ratio	**Financial leverage**	Ability of the firm to leverage on borrowed money.
G	Ertugrul & Karakasoglu, 2009	2.908	Fixed assets / long term debt		
G	Ertugrul & Karakasoglu, 2009	2.908	Fixed assets / shareholder's equity		
G	Ertugrul & Karakasoglu, 2009	2.908	Shareholder's equity / assets		
M	Ebrahimnejad, et al. 2011	1.579	Budget control	**Financial status**	Considerations on the financial strengths and stability of the supplier with reference to the specific business unit.
M	Ebrahimnejad, et al. 2011	1.579	Profitability		
M	Ebrahimnejad, et al. 2011	1.579	Risk/return ratio		
S	Percin, 2009	1.86	Financial stability		
M	Araz, et al. 2007	1.147	Financial strength		
S	Amin & Razmi, 2009	2.908	Financial strength		
M	Kilincci & Onal, 2011	2.203	Financial status		
M	Vinodh, et al. 2011	2.203	Financial strength		

S	Chang, et al. 2010	2.627	Stability of financial affairs		
M	Aydin & Kahraman, 2010	1.471	Financial status		
S	Chen & Wu, 2011	0.8	Financial conditions		
S	Buyukozkan, et al. 2008	2.026	Financial stability		
M	Yang & Chen, 2006	0.65	Finance		
M	Yang & Chen, 2006	0.65	Turnover		
O	Dickson 1966		Financial position		
O	Muralidharan, et al. 2002		Credit rating policy		
M	Ting & Cho, 2008	2.341	Assets and debts		
M	Ting & Cho, 2008	2.341	Income and earnings		
G	Ertugrul & Karakasoglu, 2009	2.908	Assets growth	**Growth ratios**	Capacity of growing in terms of market, sales or assets.
G	Ertugrul & Karakasoglu, 2009	2.908	Operating Profit growth		
G	Ertugrul & Karakasoglu, 2009	2.908	Sales growth		
G	Ertugrul & Karakasoglu, 2009	2.908	Shareholders' equity growth		
G	Ertugrul & Karakasoglu, 2009	2.908	Cash ratio	**Liquidity ratios**	Evaluation of the capability of the company to solve short and medium terms debt repayments leveraging on cash available and generation ability.
G	Ertugrul & Karakasoglu, 2009	2.908	Current ratio		
G	Ertugrul & Karakasoglu, 2009	2.908	Quick ratio		
O	Muralidharan, et al. 2002		Liquidity		
M	Ting & Cho, 2008	2.341	Cash flow		
G	Ertugrul & Karakasoglu, 2009	2.908	Net profit margin	**Profitability**	General indexes regarding the profitability of the company.
G	Ertugrul & Karakasoglu, 2009	2.908	Return on equity		
S	Das & Buddress, 2007	1.583	Earnings		
S	Sonmez & Moorhouse, 2010	1.302	Return on investment		

Flexibility – evaluation of the flexibility of the supplier in a comprehensive way. The main dimensions considered are related to the delivery flexibility, the capacity of customization of the service, the process flexibility and the production flexibility (ability to change both type and volumes of the orders).

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
S	Jharkharia & Shankar, 2007	1.327	Flexibility in operations and delivery	**Delivery flexibility**	Flexibility in the delivery service offered by the supplier.
S	Chang, et al. 2010	2.627	Flexibility of contractors in relation to the deadline		
S	Chen & Wu, 2011	0.8	Flexibility in logistic service		
O	Muralidharan, et al. 2002		Flexibility in delivery schedule		
S	Vijayvargiya & Dey, 2010	1.302	Schedule flexibility		
M	Lee, 2009	2.908	Process flexibility	**Process flexibility**	Possibility of the supplier to change the entire process according to client's needs.
M	Demirtas & Ustun, 2008	2.175	Process flexibility		
M	Demirtas & Ustun, 2008	2.175	Response to change		
S	Amin & Razmi, 2009	2.908	Supply variety	**Production flexibility**	Flexibility of the production systems in terms of possibility of changing the volumes produces, the range and the production mix.
M	Lee, 2009	2.908	Customization		
M	Lee, 2009	2.908	Product mix flexibility		
M	Lee, 2009	2.908	Volume flexibility		
M	Lee, 2009	2.908	Emergency order processing		
S	Liu & Wang, 2009	2.908	Responsiveness		
M	Aydin & Kahraman, 2010	1.471	Changing mix of ordered items		
M	Aydin & Kahraman, 2010	1.471	Changing order volumes		
G	Bai & Sarkis, 2010	1.988	Product volume changes		
O	Muralidharan, et al. 2002		Reach to change in design		
O	Muralidharan, et al. 2002		Reach to change in mix		
O	Muralidharan, et al. 2002		React to change in volumes		
S	Sonmez & Moorhouse, 2010	1.302	Options		
S	Sonmez & Moorhouse, 2010	1.302	Range products		
S	Jharkharia & Shankar, 2007	1.327	Range of services provided		
M	Chan, et al. 2008	2.596	Flexibility and responsiveness	**Service flexibility**	Capacity of the company to change the service offered according to client's requirements.
M	Lee, 2009	2.908	Flexibility in service		
G	Bai & Sarkis, 2010	1.988	Service capability		
M	Ting & Cho, 2008	2.341	Response to change		
M	Ting & Cho, 2008	2.341	Response to inquiry		

Logistics – logistics performances of the supplier, as long as evaluation of the facilities to perform the logistic activity.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
S	Liu & Wang, 2009	2.908	Logistic equipment	**Logistics facilities**	Logistics apparatus and technology available inside the company.
M	Lee, 2009	2.908	Order lead time		
S	Bhatti, et al. 2009		Logistics apparatus		
S	Bhatti, et al. 2009		Logistics technology		
G	Tan, et al. 2008	2.205	Fill rate / Capacity	**Logistics performance**	Performances of the logistics process in terms of, for example, lead time or throughput capabilities.
G	Tan, et al. 2008	2.205	Lead time		
G	Tan, et al. 2008	2.205	Manufacturing lead time		
S	Bhatti, et al. 2009		Throughput capabilities		
S	Chen & Wu, 2011	0.8	The ability of goods tracking		

Managerial – ability of the top levels to manage the company (quality of the management and conflict solution ability), coordinate the operations (providing a good information flow) and provide and effective marketing campaign.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Ebrahimnejad, et al. 2011	1.579	Conflict resolution	**Management ability**	Capacity of the top level of managing the company and solve the conflicts.
M	Ebrahimnejad, et al. 2011	1.579	Managerial competence		
S	Percin, 2009	1.86	Management capacity		
M	Chou & Chang, 2008	2.596	Management capability		
S	Chang, et al. 2010	2.627	Capacity for specific project management items		
G	Bai & Sarkis, 2010	1.988	Conflict resolution		
S	Buyukozkan, et al. 2008	2.026	Managerial experience		
S	Jharkharia & Shankar, 2007	1.327	Quality of management		
S	Amin & Razmi, 2009	2.908	Effective marketing and promotion	**Marketing effectiveness**	Ability of the marketing function to reach the objectives.

M	Araz, et al. 2007	1.147	Information flow	**Operations control**	Ability to control and coordinate the operations, managing the information flows and the communication system.
S	Bhatti, et al. 2009		Processed data handling capabilities		
O	Dickson 1966		Communication system		
O	Dickson 1966		Operating controls		

Production – performances of the production system of the supplier, with consideration on the production capacity, the lead times and the quality level achieved, and the production practices put in place.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lam, et al. 2010	1.311	Capacity	**Production capacity**	Capacity of the production system, usually in terms of volumes.
M	Araz, et al. 2007	1.147	Capacity utilization		
M	Lee, 2009	2.908	Supplier's capability limit		
M	Lee, 2009	2.908	Supplier's capacity limit		
M	Aydin & Kahraman, 2010	1.471	Capacity		
S	Chen & Wu, 2011	0.8	Surge capability		
M	Sevkli, et al. 2007	0.56	Production capacity		
M	Yang & Chen, 2006	0.65	Production capacity		
O	Muralidharan, et al. 2002		Capacity utilization		
S	Efendigil, et al. 2008	1.057	Confirmed fill rate	**Production performances**	Performances of the production systems in terms of time, quality and defect rate. Note that this dimension contains several indexes, the decision of which one to chose is postponed until the adaptation of the model to the specific case.
S	Efendigil, et al. 2008	1.057	Total order cycle time		
M	Onut, et al. 2009	2.908	Execution time		
M	Chou & Chang, 2008	2.596	Internal rejection rate		
M	Chou & Chang, 2008	2.596	Lead time		
M	Kilincci & Onal, 2011	2.203	Lead time		
M	Vinodh, et al. 2011	2.203	Low defect rate		
S	Sun, et al. 2010		Efficiency of Order Processing		
M	Aydin & Kahraman, 2010	1.471	Defected rate product		
M	Aydin & Kahraman, 2010	1.471	Production reliability		

S	Chen & Wu, 2011	0.8	The ability of goods preservation		
G	Bai & Sarkis, 2010	1.988	Short set-up time		
M	Sevkli, et al. 2007	0.56	Lead-time		
O	Dickson 1966		Packaging ability		
O	Muralidharan, et al. 2002		Percentage rejection		
M	Demirtas & Ustun, 2008	2.175	Low defect rate		
M	Ting & Cho, 2008	2.341	Defect and scrap ratio		
M	Ting & Cho, 2008	2.341	Lead time to order		
M	Ting & Cho, 2008	2.341	Product rejection ratio		
M	Sevkli, et al. 2007	0.56	Predictive and preventive maintenance	**Production practices**	Practices adopter within the production system, for example if any predictive maintenance is made or if the techniques are updated.
M	Sevkli, et al. 2007	0.56	Transportation-storage and packaging		
M	Sevkli, et al. 2007	0.56	Up-to-date techniques and equipment		

R&D – evaluation of the company to leverage on the internal research and development function to come up with new and innovative solutions to offer to its clients. The focus is both on the effectiveness of the R&D and on the facilities to support the process.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Chou & Chang, 2008	2.596	Innovation	**R&D effectiveness**	Actual effectiveness of the R&D process. Measured, for example, as the number of new patents or product or technologies developed by the R&D department.
S	Chang, et al. 2010	2.627	Capacity for research and development		
G	Bai & Sarkis, 2010	1.988	New launch of products		
G	Bai & Sarkis, 2010	1.988	New use of technologies		
G	Bai & Sarkis, 2010	1.988	Product development time		
G	Bai & Sarkis, 2010	1.988	Research and development		
M	Chan, et al. 2008	0.774	R&D capabilities		
M	Sevkli, et al. 2007	0.56	New product development		
O	Ellram 1990		Speed in development		
S	Efendigil, et al. 2008	1.057	Research and development ratio	**R&D facilities**	Facilities and

G	Bai & Sarkis, 2010	1.988	Suppliers speed in development		technologies used in the R&D process.
O	Muralidharan, et al. 2002		R&D facilities		

Technical – technical competences and abilities owned by the potential supplier. In this category, different focuses are considered: the actual technology both and a general and in a specific sense, the characteristics of the technical system and the considerations on the technology level that the company will have in the future.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lee, 2009	2.908	Future manufacturing capabilities	**Future technology**	Assessment of the future potentialities of the technological solutions of the company.
M	Lee, 2009	2.908	Future technology development		
G	Bai & Sarkis, 2010	1.988	Assessment of future manufacturing capabilities		
M	Chan, et al. 2008	0.774	Adaptability to future IT market requirements.		
O	Ellram 1990		Future technology		
M	Chou & Chang, 2008	2.596	Technical problem-solving	**Specific technological competences**	These indexes are referred to specific competences of the company. Note that, when developing the model, these specific competences have to be defined according to the particular needs.
S	Liu & Wang, 2009	2.908	EDI capacity		
G	Tan, et al. 2008	2.205	Transportation support		
S	Chang, et al. 2010	2.627	Capacity for system integration		
S	Chen & Wu, 2011	0.8	IT system capability		
G	Bai & Sarkis, 2010	1.988	Current manufacturing facilities		
G	Bai & Sarkis, 2010	1.988	Suppliers design capability		
M	Chan, et al. 2008	0.774	IT experience		
M	Yang & Chen, 2006	0.65	IT systems		
S	Bhatti, et al. 2009		Achievement monitoring capabilities		
S	Bhatti, et al. 2009		EDI facilities		
S	Bhatti, et al. 2009		IT-enabler network		
O	Muralidharan, et al. 2002		Range of products supplier could make		
O	Muralidharan, et al. 2002		Technical problem solving		
S	Jharkharia & Shankar, 2007	1.327	It capability		

M	Ebrahimnejad, et al. 2011	1.579	Technical implications	**Technical ability**	General indicator of the technology and technical level of the company. Note that this is only a general index.
M	Ebrahimnejad, et al. 2011	1.579	Technical know-how		
S	Percin, 2009	1.86	Technical ability		
M	Kilincci & Onal, 2011	2.203	Technical ability		
S	Chang, et al. 2010	2.627	Software and hardware capacities		
G	Bai & Sarkis, 2010	1.988	Technical capability		
G	Bai & Sarkis, 2010	1.988	Technological capability		
S	Buyukozkan, et al. 2008	2.026	Technical ability		
M	Chan, et al. 2008	0.774	Technical know-how		
M	Chan, et al. 2008	0.774	Technological capability		
M	Sevkli, et al. 2007	0.56	Technical capability		
O	Dickson 1966		Technical capability		
M	Yang & Chen, 2006	0.65	Design & technical capability		
S	Efendigil, et al. 2008	1.057	System flexibility index	**Technical system characteristics**	Indexes to express the characteristics of the technical system, like its flexibility, the information securities or the presence of IT standards.
M	Lee, 2009	2.908	Technological system		
S	Chang, et al. 2010	2.627	Development tools of the system		
S	Chang, et al. 2010	2.627	Information security techniques		
M	Chan, et al. 2008	0.774	Existence of IT standards		

2.3 COST

Category that includes all the types of cost related to the supply of the service or the product, starting from the direct cost of the product, passing from the indirect costs and the operative running costs.

Implementation costs – costs linked to the installation and customization of the solution inside the customer's organization. Training efforts are also included in the computation.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
S	Amin & Razmi, 2009	2.908	Installation fee	**Installation & customization**	Costs related to the installation, the integration and the customization of the solution with the already used information system, or process, of the company.
S	Das & Buddress, 2007	1.583	Integration		
S	Das & Buddress, 2007	1.583	Customization		
S	Das & Buddress, 2007	1.583	Training	**Training costs**	Costs related to any eventual training needed to implement and utilize the solution.

Operative running costs – costs linked to the utilization of the service or for maintaining the relationships with the supplier. In here, consideration on the price of the upgraded versions and on the cost of any eventual compliance are included.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Bai & Sarkis, 2010	1.988	Compliance with sectorial price behavior	**Compliance costs**	Any possible costs derived from solving some problems and compliances with the supplier.
G	Bai & Sarkis, 2010	1.988	Compliance with cost analysis system		
S	Das & Buddress, 2007	1.583	Upgrade	**Cost of Upgrade**	Cost of the new versions of the solution implemented.
S	Bhatti, et al. 2009		Maintenance cost	**Maintenance costs**	Cost of the maintenance of the solution.
S	Das & Buddress, 2007	1.583	Maintenance cost		
S	Amin & Razmi, 2009	2.908	Monthly fee	**Minimum fee**	Minimum monthly or yearly fee that the customer has to pay to the supplier to independently from the service usage.
M	Lee, 2009	2.908	Cost of forming the relationship	**Relationship costs**	Costs and time to develop and maintain the relationship with the supplier.
M	Lee, 2009	2.908	Time to forming the relationship		
S	Chen & Wu, 2011	0.8	The cooperation with our customer		
M	Demirtas & Ustun, 2008	2.175	Measurement and assessment cost		

Payment terms – evaluation of the presence of any potential discount of the proposed price, or the level of flexibility in the payments. Considerations on the terms of the contract, such as minimum duration of the supply or legal claims, are included.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lam, et al. 2010	1.311	Price stability	**Discount flexibility**	Any possible discounts deriving from negotiation or big volumes.
G	Tan, et al. 2008	2.205	Discount		
M	Chan, et al. 2008	0.774	Attractive credit terms		
M	Chan, et al. 2008	0.774	Attractive discounts		
S	Das & Buddress, 2007	1.583	Scalability		
O	Muralidharan, et al. 2002		Quantity discount		
M	Lam, et al. 2010	1.311	Payment terms	**Payment flexibility**	Flexibility in the payment due to the supplier, mainly in terms of time.
G	Liou & Chuang, 2010	1.924	Flexibility in billing		
G	Tan, et al. 2008	2.205	Payment terms		
M	Chan, et al. 2008	0.774	Negotiability		
S	Jharkharia & Shankar, 2007	1.327	Flexibility in billing and payment		
S	Jharkharia & Shankar, 2007	1.327	Clause for arbitration and escape	**Terms of contract**	Legal implication derived from the contract, for example the minimum number of months to pay for the service.
M	Ebrahimnejad, et al. 2011	1.579	Terms of contract		
M	Ebrahimnejad, et al. 2011	1.579	Legal implications		

Product cost – cost arising at the moment of the purchase of the good, both in a direct way (price of the good), and on indirect costs, such as transportation or ordering costs.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lee, 2009	2.908	Extra cost	**Other costs**	Other costs related to the purchasing, for example ordering costs.
G	Tan, et al. 2008	2.205	Other costs		
G	Faez, et al. 2009	2.068	Ordering costs		
M	Ting & Cho, 2008	2.341	Ordering costs		
M	Lam, et al. 2010	1.311	Total cost	**Price**	Direct price of the product or

S	Efendigil, et al. 2008	1.057	Unit operation cost		service.
G	Razmi, et al. 2009	1.491	Price		
M	Amin & Razmin, 2011	2.203	Unit cost		
M	Chou & Chang, 2008	2.596	Unit price		
M	Kilincci & Onal, 2011	2.203	Product price		
M	Lee, 2009	2.908	Freight price		
M	Lee, 2009	2.908	Product price		
S	Liu & Wang, 2009	2.908	Price		
M	Onut, et al. 2009	2.908	Cost		
S	Sun, et al. 2010		Service price		
S	Sun, et al. 2010		Variable cost		
G	Tan, et al. 2008	2.205	Price		
M	Aydin & Kahraman, 2010	1.471	Cost		
S	Chen & Wu, 2011	0.8	Price		
G	Bai & Sarkis, 2010	1.988	Low initial price		
G	Faez, et al. 2009	2.068	Unit cost		
M	Sevkli, et al. 2007	0.56	Price		
M	Yang & Chen, 2006	0.65	Cost		
S	Das & Buddress, 2007	1.583	Purchase		
O	Muralidharan, et al. 2002		Cost		
M	Ting & Cho, 2008	2.341	Product price		
S	Sun, et al. 2010		Transaction fee	**Transportation cost**	Cost related to the transportation of the goods purchases.
G	Tan, et al. 2008	2.205	Logistics		
G	Faez, et al. 2009	2.068	Transportation costs		
O	Muralidharan, et al. 2002		Transportation cost		
S	Vijayvargiya & Dey, 2010	1.302	Inland transport and other		
S	Vijayvargiya & Dey, 2010	1.302	Ocean/Air freight		
M	Ting & Cho, 2008	2.341	Transportation costs		

2.4 GREEN AND ENVIRONMENT

This macro category derives from the recent attention in green issues arose among the business actors. In here, the "green" level of the supplier is evaluated, as long as the impact of the supplier inside the local environment (in a broad sense).

Emission – evaluation of the emission level of the supplier, both in terms of pollution production and in terms of resource consumptions

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Yeh & Chuang, 2011	2.203	Air pollution	**Pollution/waste production**	Evaluation of the pollution produced in terms of air pollution, toxic products and waste production.
G	Yeh & Chuang, 2011	2.203	Cadmium content		
G	Yeh & Chuang, 2011	2.203	Led content		
G	Yeh & Chuang, 2011	2.203	Mercury content		
G	Bai & Sarkis, 2010	1.988	Production of polluting agents		
G	Bai & Sarkis, 2010	1.988	Production of toxic products		
G	Bai & Sarkis, 2010	1.988	Production of waste		
G	Bai & Sarkis, 2010	1.988	Consumption of energy	**Resources consumption**	Utilization of the natural resources such as water, raw material or energy.
G	Bai & Sarkis, 2010	1.988	Consumption of raw material		
G	Bai & Sarkis, 2010	1.988	Consumption of water		

Environmental care – evaluation of the policies and practices that the company adopts to respect the environment. The focus of these indexes is not limited to the environment in the sense of nature, but also to the policies towards the local community and the "green" position of the company.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
G	Bai & Sarkis, 2010	1.988	Collective audience	**External social criteria**	Initiatives focused specifically on the local community on the social side.
G	Bai & Sarkis, 2010	1.988	Consumers education		
G	Bai & Sarkis, 2010	1.988	Cultural properties		
G	Bai & Sarkis, 2010	1.988	Decision influence potential		
G	Bai & Sarkis, 2010	1.988	Economic welfare and growth		
G	Bai & Sarkis, 2010	1.988	Education		

G	Bai & Sarkis, 2010	1.988	Grants and donations		
G	Bai & Sarkis, 2010	1.988	Health		
G	Bai & Sarkis, 2010	1.988	Housing		
G	Bai & Sarkis, 2010	1.988	Mobility infrastructure		
G	Bai & Sarkis, 2010	1.988	Partnership screens and standards		
G	Bai & Sarkis, 2010	1.988	Procurement standard		
G	Bai & Sarkis, 2010	1.988	Regulatory and public services		
G	Bai & Sarkis, 2010	1.988	Security		
G	Bai & Sarkis, 2010	1.988	Selected audience		
G	Bai & Sarkis, 2010	1.988	Sensory stimuli		
G	Bai & Sarkis, 2010	1.988	Service infrastructure		
G	Bai & Sarkis, 2010	1.988	Social cohesion		
G	Bai & Sarkis, 2010	1.988	Social pathologies		
G	Bai & Sarkis, 2010	1.988	Stakeholder empowerment		
G	Bai & Sarkis, 2010	1.988	Stakeholder engagement		
G	Bai & Sarkis, 2010	1.988	Supporting community projects		
G	Bai & Sarkis, 2010	1.988	Supporting educational institutions		
M	Lee, 2009	2.908	Inadequate environmental controls and programs	**Green position**	Assessment of the reputation of the company as “green” company.
G	Yeh & Chuang, 2011	2.203	Customer’s purchase or not		
G	Yeh & Chuang, 2011	2.203	Green customer’s market share		
M	Ebrahimnejad, et al. 2011	1.579	Environmental projection	**Green/ environmental policies**	Consideration of the policies and practices adopted by the company to protect the environment, reducing the emissions and working for “greener” products. In addition, indexes to measure how the company interacts with the local community and the local environment are included.
M	Ebrahimnejad, et al. 2011	1.579	Public relation		
S	Efendigil, et al. 2008	1.057	Environmental expenditures		
G	Yeh & Chuang, 2011	2.203	Air pollution treatment cost		
G	Yeh & Chuang, 2011	2.203	Chemical wastes treatment cost		
G	Yeh & Chuang, 2011	2.203	Energy consumption costs		
G	Yeh & Chuang, 2011	2.203	Environmental protection plans		
G	Yeh & Chuang, 2011	2.203	Environmental protection policies		
G	Yeh & Chuang, 2011	2.203	Passing ISO 14000 verification		
G	Yeh & Chuang, 2011	2.203	Recycling product design of suppliers		

G	Yeh & Chuang, 2011	2.203	Recycling rate		
G	Yeh & Chuang, 2011	2.203	Renewable product design of suppliers		
G	Yeh & Chuang, 2011	2.203	Reverse logistics		
G	Yeh & Chuang, 2011	2.203	Solid waste treatment costs		
G	Yeh & Chuang, 2011	2.203	Water pollution treatment cost		
G	Bai & Sarkis, 2010	1.988	Assignment of environmental responsibility		
G	Bai & Sarkis, 2010	1.988	Checking and evaluation of environmental activities		
G	Bai & Sarkis, 2010	1.988	End-of-pipe controls		
G	Bai & Sarkis, 2010	1.988	Establishment of environmental commitment and policy		
G	Bai & Sarkis, 2010	1.988	Identification of environmental aspects		
G	Bai & Sarkis, 2010	1.988	Planning of environmental objectives		
G	Bai & Sarkis, 2010	1.988	Process adaptation		
G	Bai & Sarkis, 2010	1.988	Product adaptation		
G	Bai & Sarkis, 2010	1.988	Remediation		

2.5 SOLUTION

This main category includes the evaluation of the solution proposed by the supplier. The solution is seen in a comprehensive way, including the services and the support offered, the characteristics and the quality level of the solution.

Quality – assessment of the quality of the solution offered, divided under three main dimensions: delivery, service and product quality. Note that in this category the quality is strictly referred to the solution offered, and for this reasons consideration on the internal quality system and performances are not include. The term "quality" used in this group of indexes can be referred to the term "quality conformance" introduced by Morse (1983). Morse (1983) defined quality conformance as "*the degree of correspondence between the customer's actual experience with a product and the product's designed quality*[43]." (Morse, 1983).

[43] "*Quality of design represents the planned quality of a product*" (Morse, 1983).

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lam, et al. 2010	1.311	On time delivery	**Delivery quality**	Quality related to the delivery of the product, with reference to, for example, the percentage of on-time delivery, or the reliability of the supply.
M	Lam, et al. 2010	1.311	Reliability		
S	Efendigil, et al. 2008	1.057	On time delivery ratio		
M	Amin & Razmin, 2011	2.203	On time delivery		
M	Chamodrakas, et al. 2010	1.924	Compliance with due date		
M	Chan, et al. 2008	2.596	Delivery reliability		
M	Chan, et al. 2008	2.596	Reliable delivery		
M	Lee, 2009	2.908	Delivery reliability		
M	Lee, 2009	2.908	On time delivery		
M	Lee, 2009	2.908	Distribution network quality		
G	Liou & Chuang, 2010	1.924	On time delivery		
S	Liu & Wang, 2009	2.908	On-Time shipments and delivery		
M	Vinodh, et al. 2011	2.203	On time delivery		
S	Sun, et al. 2010		Accuracy delivery rate		
S	Sun, et al. 2010		On time delivery		
G	Tan, et al. 2008	2.205	On time delivery		
M	Aydin & Kahraman, 2010	1.471	On time delivery		
S	Chen & Wu, 2011	0.8	Delivery conforms to regulation		
S	Chen & Wu, 2011	0.8	On time delivery		
G	Bai & Sarkis, 2010	1.988	Consistent delivery		
G	Faez, et al. 2009	2.068	Percent of on-time delivery		
M	Sevkli, et al. 2007	0.56	Shipment quality		
M	Demirtas & Ustun, 2008	2.175	On time delivery		
M	Ting & Cho, 2008	2.341	Delivery time delays		
M	Ting & Cho, 2008	2.341	Delivery quantity shortage		
M	Lam, et al. 2010	1.311	Appearance and functions	**Product quality**	Quality related to any physical product offered. It includes the percentage of wasted items, the conformance with
M	Lam, et al. 2010	1.311	Failures prevention		
M	Araz, et al. 2007	1.147	Non damaged items		
M	Chamodrakas, et al. 2010	1.924	Compliance with quality		

M	Chan, et al. 2008	2.596	Conformance to specification		specification and any past quality complaints.
M	Chan, et al. 2008	2.596	Product reliability		
M	Kilincci & Onal, 2011	2.203	Product quality		
M	Kilincci & Onal, 2011	2.203	Professionalism		
M	Onut, et al. 2009	2.908	Quality of the products		
G	Tan, et al. 2008	2.205	Product quality		
S	Chang, et al. 2010	2.627	Property, quality and reliability of products		
M	Aydin & Kahraman, 2010	1.471	Apparent quality		
M	Aydin & Kahraman, 2010	1.471	Conformance to specification		
G	Bai & Sarkis, 2010	1.988	Conformance to specification		
G	Faez, et al. 2009	2.068	Percent of warranty claims		
G	Faez, et al. 2009	2.068	Percent of waste items		
S	Efendigil, et al. 2008	1.057	Service quality level	**Service quality**	Quality of the service provided, with reference to the reliability and the service quality level.
S	Amin & Razmi, 2009	2.908	Speed		
S	Amin & Razmi, 2009	2.908	Accessibility		
S	Amin & Razmi, 2009	2.908	Reliability		
M	Chan, et al. 2008	2.596	Customer response		
M	Lee, 2009	2.908	Quality of support services		
M	Lee, 2009	2.908	Product reliability		
S	Liu & Wang, 2009	2.908	Service quality		
M	Vinodh, et al. 2011	2.203	Quick responsiveness		
G	Faez, et al. 2009	2.068	Average Response time of each claim		

Solution characteristics – specifications of the solution or product proposed. The attention is both on specific characteristics of the product, such as the technology adopted, the product features or the solution delivery, and on a more comprehensive focus, including the duration of the project to set up the solution, its implementability in the client's structure and the cost reduction obtainable from the implementation.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Lee, 2009	2.908	Cost reduction	**Cost reduction**	Assessment of the reduction of costs derived from the implementation of the solution in the customer's company.
M	Vinodh, et al. 2011	2.203	Improved process capability		
M	Chou & Chang, 2008	2.596	Cost reduction		
G	Liou & Chuang, 2010	1.924	Cost saving		
S	Chen & Wu, 2011	0.8	Enhanced operational efficiency		
G	Bai & Sarkis, 2010	1.988	Cost reduction		
M	Vinodh, et al. 2011	2.203	Supplier capacity	**Facilities**	Support facilities used to provide the service and the product.
M	Aydin & Kahraman, 2010	1.471	Distribution and storage facility		
S	Das & Buddress, 2007	1.583	Implementation time	**Implementability**	Easiness and flexibility of the solution to be applied in the new client's information systems.
S	Das & Buddress, 2007	1.583	Product can be supported by other supplier		
M	Kilincci & Onal, 2011	2.203	Follow-up	**Product features**	Characteristics and features of the solution offered, for example the duration of the warranty or the innovation level of the solution.
M	Kilincci & Onal, 2011	2.203	Handling		
M	Aydin & Kahraman, 2010	1.471	Warranty period and insurance		
S	Bhatti, et al. 2009		Scope of services		
O	Dickson 1966		Warranties and claims		
O	Pan 1989		Service constrains		
S	Sonmez & Moorhouse, 2010	1.302	Effective solution		
S	Sonmez & Moorhouse, 2010	1.302	Meet client needs		
S	Sonmez & Moorhouse, 2010	1.302	Latest innovative methods		
M	Ebrahimnejad, et al. 2011	1.579	Project duration	**Project**	Specifications regarding the characteristics of the project (if the solution is provided in project form). For example the duration or the completions date.
G	Razmi, et al. 2009	1.491	Finish time		
M	Araz, et al. 2007	1.147	Delivery performance	**Solution delivery**	Speed and performances of the delivery of the product or the service.
M	Onut, et al. 2009	2.908	Delivery time		
G	Tan, et al. 2008	2.205	Delivery lead time		

S	Chen & Wu, 2011	0.8	Delivery performance		
G	Bai & Sarkis, 2010	1.988	Delivery speed		
G	Faez, et al. 2009	2.068	Order Delivery time		
M	Sevkli, et al. 2007	0.56	Delivery		
M	Yang & Chen, 2006	0.65	Delivery		
S	Bhatti, et al. 2009		Time to transport		
O	Dickson 1966		Delivery		
O	Muralidharan, et al. 2002		Delivery speed		
S	Jharkharia & Shankar, 2007	1.327	Delivery performance		
S	Efendigil, et al. 2008	1.057	Integration level index	**Technology adopted**	Type of technology used in the solution.
M	Sevkli, et al. 2007	0.56	EDI		
M	Sevkli, et al. 2007	0.56	Internet		
M	Sevkli, et al. 2007	0.56	RFID		
S	Bhatti, et al. 2009		ERP competence		
S	Das & Buddress, 2007	1.583	Product technology		

Support and service – range and type of services (and products) offered by the company in addition to the primary product or service. Any support activity during and after the implementation is included too. Note that this is just a preliminary aggregation of the different possible product that the supplier can offer. Which one to include or not, has to be decided when the problems will be modeled for the specific purpose.

Cat	Authors	Impact factor	Original Criterion	Criterion defined	Description
M	Chan, et al. 2008	2.596	After-sales service	**Customer service**	Assistance during and after the implementation of the solution.
S	Liu & Wang, 2009	2.908	Customer service		
M	Aydin & Kahraman, 2010	1.471	Whole year availability		
M	Yang & Chen, 2006	0.65	Customer service		
O	Dickson 1966		Repair service		
S	Das & Buddress, 2007	1.583	24/7 after sales support		
O	Muralidharan, et al. 2002		After sales service		

O	Muralidharan, et al. 2002		Availability of spare parts		
M	Lam, et al. 2010	1.311	Technical assistance & support	**Technical support**	Assistance under a technical focus, mainly during the implementation and in the startup phase.
M	Kilincci & Onal, 2011	2.203	Technical support		
M	Lam, et al. 2010	1.311	Cooperation & communication	**Value added service**	All the other possible services available for the customer.
M	Chan, et al. 2008	2.596	Assurance about the handling of problems		
M	Chan, et al. 2008	2.596	Existence of a refund policy		
M	Chan, et al. 2008	2.596	Formation sharing		
S	Liu & Wang, 2009	2.908	Accessibility of contact person in urgency		
S	Liu & Wang, 2009	2.908	Value added service		
M	Aydin & Kahraman, 2010	1.471	Repair turn round time		
M	Aydin & Kahraman, 2010	1.471	Information sharing		
O	Dickson 1966		Training aids		
S	Sonmez & Moorhouse, 2010	1.302	Opportunity to test		
S	Sonmez & Moorhouse, 2010	1.302	Train internal personnel		
S	Sonmez & Moorhouse, 2010	1.302	Bring added value		
S	Vijayvargiya & Dey, 2010	1.302	Clearing & forwarding		
S	Vijayvargiya & Dey, 2010	1.302	IT-Track & trace		
S	Vijayvargiya & Dey, 2010	1.302	Port licensing & presence		
S	Vijayvargiya & Dey, 2010	1.302	Warehousing		

3. INDEXES SELECTION

Once the new indexes have been defined, the following step is to select the best ones and the most appropriate for the specific case considered.

In order to select the best ones, different steps have been done.

1. Each new criterion defined has been evaluated. Each new criterion (the criteria derived from the aggregation of the original ones) defined received a ranking based on the number and the relevance of the original criteria included. For a more complete evaluation, different types of weights have been considered in order to provide a sensitivity analysis on the results.
2. The worst indicators have been eliminated (always checking if there is any particular important indicator for the contest to be included in the model).
3. The non-related second-level categories have been eliminated a priori.
4. Among the best ones, the most appropriate have been derived.
5. The coverage of the main areas has been verified.
6. Finally, with the collaboration of the experts of the Observatory of Politecnico di Milano, the set of indexes have been validated.

3.1 DEFINITION OF THE INDEXES' RANKING

In order to give a rank to the indexes identified, the following steps have been followed:

1. The possible impact factors have been grouped together in 6 clusters:

From 0 to 0.5	From 0.5 to 1	From 1 to 1.5	From 1.5 to 2	From 2 to 2.5	From 2.5 to 3

2. Per each new criterion defined, the different original criteria have been considered. For example, for the criterion "strategic alliances" we have:

Cat	Author	Impact factor	Original Criteria	Criterion defined
M	Lam, et al. 2010	1.311	Buyer supplier relationship	**Strategic alliances**
S	Percin, 2009	1.86	Strategic partnerships	
S	Amin & Razmi, 2009	2.908	Strategic alliances	
M	Lee, 2009	2.908	Stabilized relationship	
G	Liou & Chuang, 2010	1.924	Relationship	
G	Bai & Sarkis, 2010	1.988	Long term relationship	
S	Buyukozkan, et al. 2008	2.026	Sustainable relationship	
S	Sonmez & Moorhouse, 2010	1.302	Membership	

S	Sonmez & Moorhouse, 2010	1.302	Personal relationship	
S	Sonmez & Moorhouse, 2010	1.302	Successful relationships	

3. Inside the criterion, per each category, the number of different authors belonging to the specific impact factors cluster has been calculated. For example, for "strategic alliances" we have:

Impact factor / Category	From 0 to 0.5	From 0.5 to 1	From 1 to 1.5	From 1.5 to 2	From 2 to 2.5	From 2.5 to 3
S			1	1	1	1
M			1			1
G				2		

Note that the number of <u>different</u> authors has been considered, so, if like this case, the criterion contains 3 original indexes coming from the same author, the impact factor has just been considered once.

4. In this way we have obtained two dimensions: the category in which the author belongs to (i.e. service, material, general or old) and the impact factors of the paper (clustered in 6 groups). In order to integrate these dimensions, the weighted average has to be calculated. As there is no the best weight, five different rakings has been calculated, each of these ranks has different weights and give different level of relevance to the dimensions.

   It is logics though, that these considerations can be done:

   - ✓ the papers belonging to the category Service (S) will have the higher importance, followed by General (G) and Material (M);
   - ✓ the papers with impact factor higher will have an higher relevance compared to a lower impact factor.

   These different evaluations can be seen in the following table:

	Category			Impact factor					Note
	S	**M**	**G**	**0.5-1**	**1-1.5**	**1.5-2**	**2-2.5**	**2.5-3**	
Rank 1	3	1	2	1	2	3	4	5	Balanced scenario. The weights of both the dimensions follow a linear growth.
Rank 2	1	1	1	1	2	3	4	5	The category is not considered, while the impact factor has a linear evolution.

Rank 3	3	1	2	1	2	4	8	16	The category is considered in a linear way, while the impact factors are exponential. In this case the focus is on the impact factor.
Rank 4	8	2	4	1	2	3	4	5	In this case the focus is put on the category dimension, with an exponential growth of the weights, while the impact factor is linear.
Rank 5	8	2	4	1	2	4	8	16	Both the dimensions are empathized, giving a higher relevance to the service category and the high impact factors.

Note that, as the category Old (O) has no impact factor defined (for the reasons already explained), in this model that category is not considered. It still has to be stated that, if the criterion belonging to the Old category was worth using, some more recent authors had for sure used it in their model, so that the criterion is yet included in the model (but under a different author).

3.2 ELIMINATION OF THE WORST INDICATORS

The five different rankings can give us a comprehensive idea of the relevance of each specific indicator. For this reason, the last 21 indicators (25% of the total[44]) can be eliminated (except for some indicators of particular relevance). As some criteria can be "saved", the process has to be redone until exactly 21 indicators have been eliminated.

#	Criterion	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Particularly important?
53	Marketing effectiveness	53	73	41	48	37	No
54	Minimum fee	54	74	42	49	38	Yes
55	Dimension	55	60	63	51	59	Yes
56	Liquidity ratios	56	54	47	58	44	No
57	Pollution/waste production	57	59	61	55	60	No
58	Green position	58	53	52	66	56	No
59	Employment practices	59	64	68	54	66	No
60	Future technology	60	52	60	67	64	No
61	R&D facilities	61	66	69	56	70	No
62	Relationship costs	62	51	58	68	62	Yes
63	Product features	63	58	67	64	72	Yes
64	Logistics performance	64	72	65	62	63	No
65	Activity ratios	65	68	50	70	50	No
66	Financial leverage	66	69	51	71	51	No
67	Growth ratios	67	70	53	72	52	No
68	Cost of Upgrade	68	76	70	60	65	Yes

[44] In this way the last Quartile of the total number is eliminated.

69	Implementability	69	78	71	61	67	Yes
70	Maintenance costs	70	79	72	63	68	Yes
71	Process flexibility	71	55	62	75	69	No
72	Terms of contract	72	67	77	69	74	Yes
73	Training costs	73	81	73	65	71	Yes
74	Environment characteristics	74	56	64	80	73	No
75	Industry reputation	75	71	74	74	75	No
76	Project	76	65	80	76	82	Yes
77	Compliance costs	77	75	78	77	76	Yes
78	External social criteria	78	77	79	78	77	No
79	Payments terms	79	84	82	73	78	No
80	Resources consumption	80	80	81	79	79	No
81	Facilities	81	61	75	82	80	No
82	Technical support	82	62	76	83	81	Yes
83	Company's rank	83	82	83	81	83	No
84	Operations control	84	83	84	84	84	No
85	Production practices	85	85	85	85	85	No

3.3 ELIMINATION OF THE NOT-RELATED DIMENSIONS

Given the service dimension of the specific product considered in this model, some entire categories can be eliminated a-priori.

- *Logistics* – this dimension was related mainly with papers in which the delivery and the logistics processes were particularly important. In this case, no logistics performances are needed, so this cluster can be eliminated.
- *Production* – as the previous cluster, the “production” dimension derived from the evaluation of the capabilities of a supplier when considering the material purchasing case. In the case considered, no production capability has to be assessed, as no particular item has to be produced.

3.4 SELECTION OF THE BEST ONES

After these two initial steps, 48 indexes remained. These indexes has to be analyzed one-by-one in order to decide if they are suitable or not, and if there is the possibility to merge different indicators in a more comprehensive one.

Note that, according to several authors (Macharis, et al., 2004; Saaty & Vargas, 1996), the correct number of indexes for an AHP model should be 20/25.

#	Criterion	Description	Used?	Notes
1	Price	Direct price of the product or service.	Yes	
2	Financial status	Considerations on the financial strengths and stability of the supplier.	Yes	
3	Relationship closeness	How tight the actual relationships are. It considers the frequency of the communications between the actors as long as which are the processes shared.	Yes	
4	Strategic alliances	Strategic alliances, partnerships and memberships that the company has at time now, or that had in the past and can guarantee with recorded data.	Yes	
5	Management ability	Capacity of the top level of managing the company and solve the conflicts.	Yes	
6	Specific technological competences	This index is referred to specific competences of the company. Note that, when developing the model, these specific competences have to be defined according to the particular needs.	Merge	As the internal technical system is strongly related to the technical specification of the solution proposed, this index can be merged with “Technical system characteristics”. Secondly, as the technology considered has only a specific focus, this index can be merged with “Technical ability”.
7	Cultural fit	Similarities and compatibility between supplier’s and client’s cultures. The cultures' fit if they share the same values and procedures.	Merge	Given the general high level of this evaluation, there is no need to differentiate between cultural, strategic and organizational fit, but they can be merged in one new index called “Compatibility”.
8	Product quality	Quality related to any physical product offered. It includes the percentage of wasted items, the conformance with specification and any past quality complaints.	Merge	This index has to be merged with “service quality” according to the type of solution offered (the solution can be sold as a product or as a service).
9	Quality system	Presence or not of a quality system. Further indexes can regard any possible	Yes	

		quality certificates, the quality philosophy or the quality assurance techniques.		
10	Service quality	Quality of the service provided, with reference to the reliability and the service quality level.	Merge	Merge with “Product quality”
11	Specific experiences	Experience related to a specific product, industry or sector of the potential supplier.	Merge	In this case, the experiences required are only related to a specific case. For this reason this index can be merged, or better, it could include the “previous experience” one.
12	Employee composition	Composition of the internal workforce, in terms of number of employees, as long as gender composition or cultural diversity.	Yes	The composition in terms of technical and commercial employee is important.
13	Operational risks	Risks related to the normal operations of the supplier. For example the security level of the internal communication systems, or of the internal data sharing system. Any past case of lawsuits or problems with previous clients can be considered too.	Yes	In particular the security level of the information flow is important.
14	Technical ability	General indicator of the technology and technical level of the company. Note that this is only a general index.	Merge	Merge with “Technical system characteristics” and “Specific technological competences”.
15	General reputation	General perception of supplier’s honesty, believability and reliability within the business.	Yes	
16	Market knowledge	General knowledge of the market, given by, for example, the time spent in the business. Note that this is a general evaluation of the experience of the supplier not referred to any specific industry.	Yes	
17	Previous experiences	Recorded examples of past experiences of the supplier, both in a global sense, and with respect to the any specific previous cooperation with the customer.	Merge	Merge with “specific experience”
18	Value added service	All the other possible services available for the customer	Yes	In this index the services proposed will be defined later.
19	Managerial practices	Series of practices and methods adopted by the management. Example can be the presence or not of a performance measurement system or the inspection method adopted.	No	As we are talking also about small-medium entities, the managerial practices may not be present or defined (and this index would favor the big realties).
20	Customer service	Assistance during and after the implementation of the solution.	Yes	
21	Economic status	General evaluation of the economic status of the company. Note that this is	Yes	

		just a general consideration, as a more specific evaluation is included in the financial performances.		
22	Volume of business	Market share of the company, operational boundaries and geographical spread to evaluate the volume of the company's business referred to the global market.	Yes	
23	Cost reduction	Assessment of the reduction of costs derived from the implementation of the solution in the customer's company.	No	The cost reduction depends on the level of integration (Observatory on Electronic Invoicing and Dematerialization, 2010) and not on the specific solution proposed by the supplier.
24	Technical system characteristics	Indexes to express the characteristics of the technical system, like its flexibility, the information securities or the presence of IT standards.	Merge	Merged with "Technical ability" and "Specific technological competences".
25	Profitability	General indexes regarding the profitability of the company.	No	Given that this phase includes a high level analysis, this index can be eliminated, or included in the "economic status" of the supplier.
26	Other costs	Other costs related to the purchasing, for example ordering costs.	Yes	
27	Eagerness to cooperate	How much the company is willing to set new relationships. Measured, for example, as the time required for setting a new relationship, or as the willingness of the supplier to participate to customer's operations.	Yes	
28	Installation & customization	Costs related to the installation, the integration and the customization of the solution with the already used information system, or process, of the company.	Yes	
29	Green/ environmental policies	Consideration of the policies and practices adopted by the company to protect the environment, reducing the emissions and working for "greener" products. In addition, indexes to measure how the company interacts with the local community and the local environment are included.	Yes	This index will include all the considerations regarding the green aspects of the supplier
30	Strategic fit	Alignment and compatibility between the strategies of the two actors.	Merge	This index is merged in "Compatibility" (see "Cultural fit" index for further details).
31	Organizational fit	Similarities and compatibility between the two companies' structures in terms of dimensions, internal organization and HR policies.	Merge	This index is merged in "Compatibility" (see "Cultural fit" index for further details).
32	Management stability	Stability of the management at the top level of the organization in order to guarantee constant commitment with the client.	No	We are not talking to strategic partnerships in which the commitment of the management is fundamental. In this case the management can also change, as long as the contract is respected.

33	Discount flexibility	Any possible discounts deriving from negotiation or big volumes.	Yes	
34	Service flexibility	Capacity of the company to change the service offered according to client's requirements.	Yes	
35	Customer loyalty	Satisfaction level and rejection rate of past and current customers.	Yes	
36	Technology Adopted	Type of technology used in the solution.	Yes	
37	Minimum fee	Minimum monthly or yearly fee that the customer has to pay to the supplier to independently from the service usage.	Yes	
38	Dimension	Size of the potential supplier.	Yes	
39	Relationship costs	Costs and time to develop and maintain the relationship with the supplier.	Yes	
40	Product features	Characteristics and features of the solution offered, for example the duration of the warranty or the innovation level of the solution.	Yes	As before, in this case it has to be considered if the solution is offered as a service or as a product.
41	Cost of Upgrade	Cost of the new versions of the solution implemented.	Yes	
42	Implementability	Easiness and flexibility of the solution to be applied in the new client's information systems.	Yes	
43	Maintenance costs	Cost of the maintenance of the solution.	Yes	
44	Terms of contract	Legal implication derived from the contract, for example the minimum number of months to pay for the service.	Yes	
45	Training costs	Costs related to any eventual training needed to implement and utilize the solution.	Yes	
46	Project	Specifications regarding the characteristics of the project (if the solution is provided in project form). For example the duration or the completions date.	Yes	
47	Compliance costs	Any possible costs derived from solving some problems and compliances with the supplier.	Yes	
48	Technical support	Assistance under a technical focus, mainly during the implementation and in the startup phase.	No	As said before, this phase of the selection assumes a high level focus. For this reason, this index can be included in the "value added service" as a possible service offered by the supplier.

3.5 COST INDEXES

Considering the particular relevance of the cost dimension in the supplier selection decision, this dimension will be kept separated from the others.

This division will enable a two-dimension comparison between the results deriving from the AHP model and the price of the solution[45], highlighting, for each alternative, the trade-off between performances and cost, delegating the final decision to the decision marker.

In particular, each dimension considered in the Cost category is easily quantifiable in terms of €/page or €/year. During the evaluation of the Total Cost, the decision maker has to take into consideration all the different dimensions identified during the analysis: in this way he/she will have a complete view of the costs of the solution.

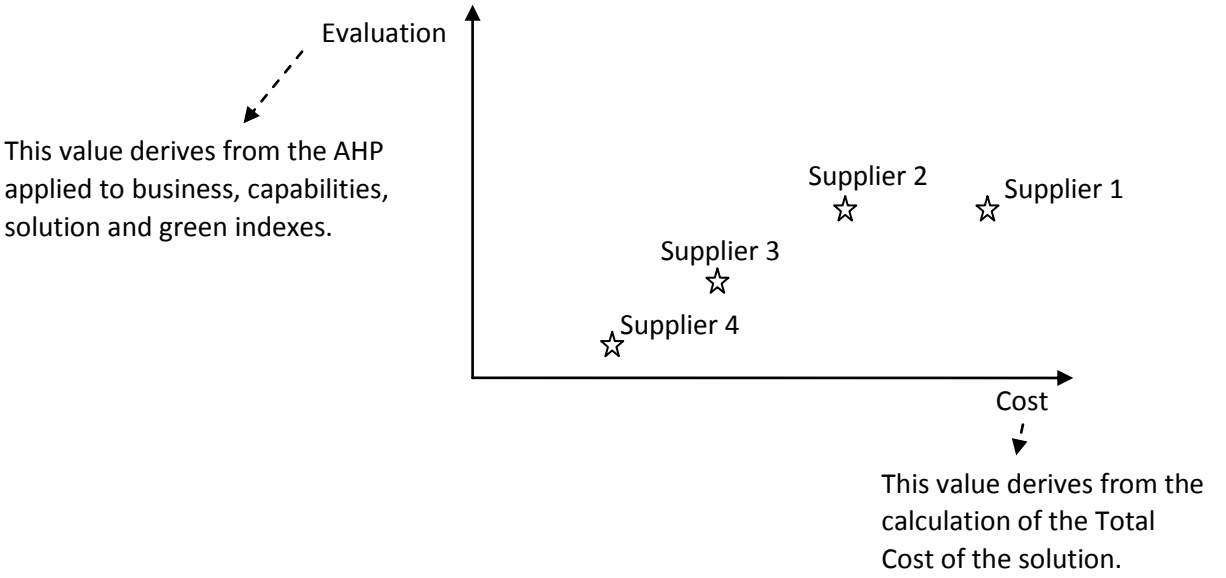
There is not just one way to calculate the Total Cost of the solution, my suggestion is to follow the following guidelines.

- *Implementation cost* – these costs are fixed, usually *una tantum*, and easily quantifiable.
- *Operative running costs* – these costs are almost fixed, but they incur more than once (usually once a year). The only problematic indexes can be "*Relationship costs*" and "*Compliance cost*". In order to evaluate these two dimensions the company has to perform and internal evaluation and ask for same previous examples to the supplier or to other companies for some feedbacks.
- *Product cost and Payment terms* – these are variable costs that depend on the volumes. These costs are also easily identifiable, but during the evaluation the user has to take into consideration the possible volumes discount ("*Discount flexibility*"). The second dimension of the payment terms is the "Terms of contract"; this criterion is referred to any possible penalties that the company has to pay for any before-end interruption of the relationship. This index may be included also in the fixed part of the costs, depending on the specific case.

How to combine these 3 dimensions strongly depends on the enterprise's sensibility: they can decide for a simple sum, expressing the total cost on a year basis [€/year] (with an estimation of the future volumes to predict the variable costs), or decide just to consider the variable costs, expressing the cost value in terms of [€/page]. A further and more precise solution is the weighted average of the 3 dimensions, with a sensitivity analysis on the weights.

[45] The evaluation of the costs can be describe as a Total Based Cost Approach.

Despite the specific model decided to perform the cost calculation, the most important consideration is the consistency of the measurement for all the suppliers.



3.6 COVERAGE CHECKING

Once the main indexes have been selected, a further checking has to be done: these criteria should cover more or less all the second-level dimensions identified, to verify if the selection process has led to the creation of some black areas (except for the ones previously identified as not relevant) or is not unbalanced towards some specific ones, causing possible biases in the evaluation.

In the following page, the tree diagram with the criteria identified can be seen. The indexes selected are highlighted in grey. As can be noticed, all the main dimensions are more or less equally covered, with the only exception of the Green & Environment one. For this reason, the second best index belonging to that category will be added to the model. The result leads to the enclosure of "Pollution/ waste reduction" criteria in the list.

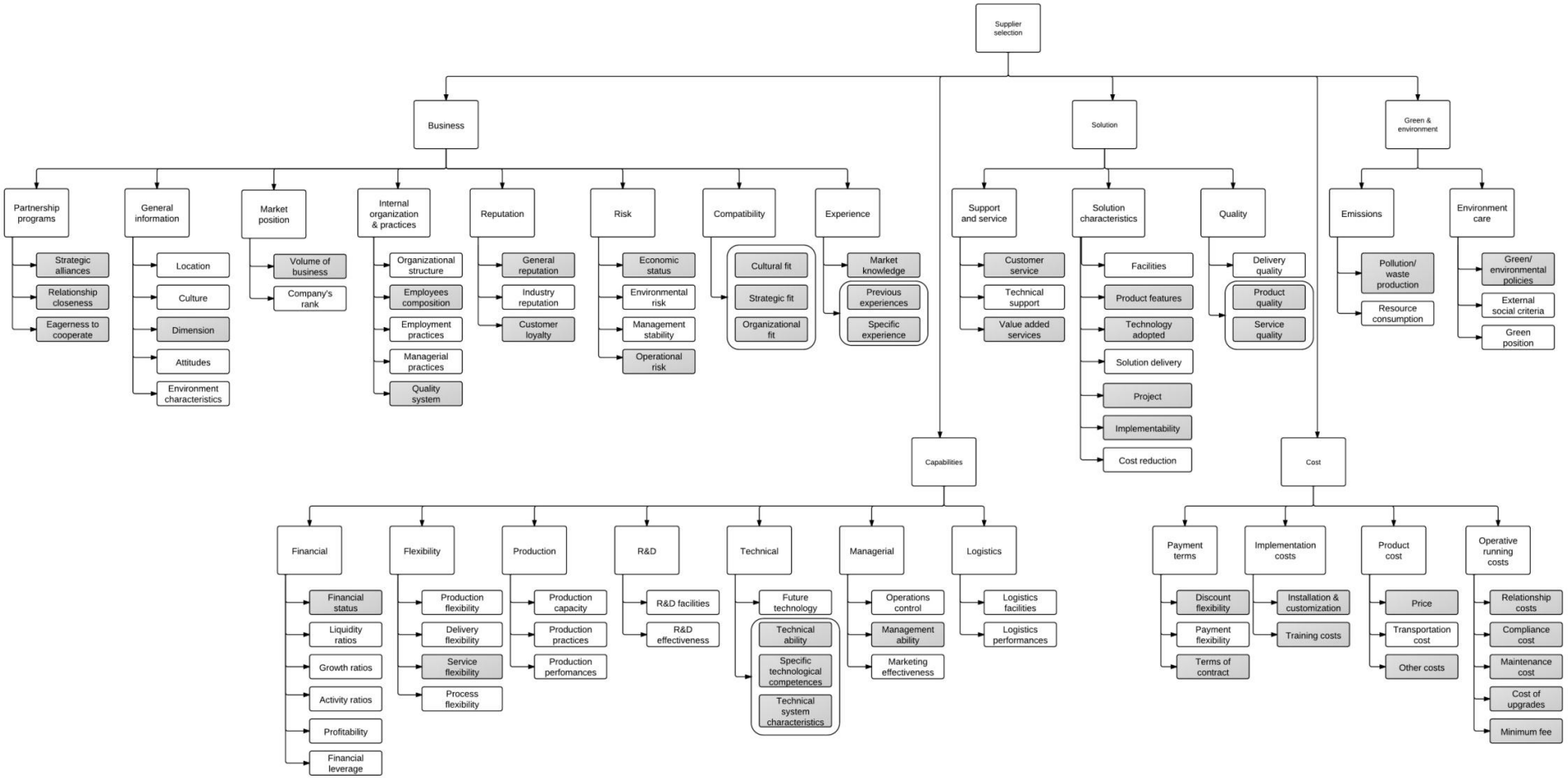


FIGURE 25 - COVERAGE CHECKING

3.7 FINAL INDEXES SELECTED

The result of the indexes selection is the following structure:

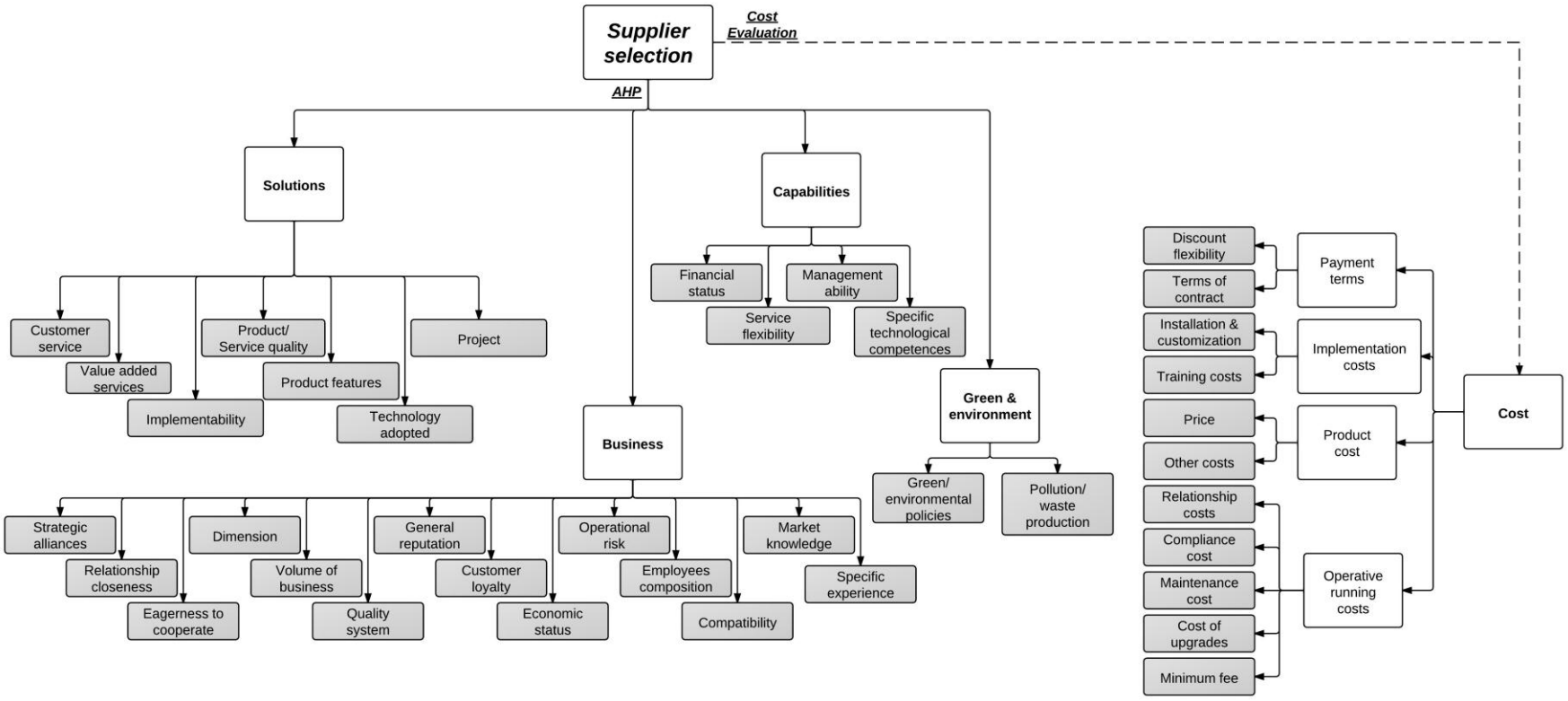


FIGURE 26 - FINAL INDEXES SELECTED

3.8 CONSIDERATIONS ON THE SELECTION PROCESS

The selection process comes out with 38 different criteria, 11 of which belonging to the "Cost" dimension: the number of indexes can be considered good with respect to the limitations required by the AHP model.

Also the coverage of the main dimensions is respect, with at least one indicator per each category (except for "R&D", "Production" and "Logistics" dimensions). In the particular case of the "Green & environmental" category, the selection process has excluded mainly all the criteria, this is due to the fact that the identification of "green" indexes is relatively new in the literature and only a couple of authors have used them.

4. WEIGHTS DEFINITION

In order to derive the single weights of each criterion, a survey was sent to the partners of the Observatory on Electronic Invoicing and Dematerialization. In an excell file, the pairwise comparisons were proposed: each user had to choice, and weight, the most important criteria among the pair.

In order to merge all the single contributions and obtain a unique one, I followed the following steps:

1. first I created the comparison matrix and derived the weights from each independent questionannaire;
2. I calculated the Consitiency Ratio for each of these single contributions. In this way, the questionnaires that did not satisfy the consistency requirements have been eliminated;
3. a new comparison matrix has been derived putting, for each comparion, the average of the evaluations belonging to the remaining contributions (=the consistent ones);
4. the weights of the obtained matrix have been calculated, as long as the consistency ratio: this ratio still respects the requirements imposed by Saaty (1980), the model is then to be considered valid.

Note that this process have been applied not only to the second-level indexes, but also to the first-level categories. In this way, multiplying the relative weight of the second-level index with the father's one, the absolute ranking can be derived.

In the following pages I will show, as an example, the overal matrix for the Business dimension. The whole set of matrixes can be found in the Validation chapter.

Business	Strategic Alliances	Relationship Closeness	Eagerness to Cooperate	Internal Dimension	Volumes of business	Internal composition	Quality System	Reputation	Customer Loyalty	Economic Status	Operational risk	Compatibility	Market knowledge	Specific Experience
Strategic Alliances	1.00	4.33	2.73	2.05	0.21	2.73	2.70	0.21	0.49	0.16	1.38	0.73	0.16	0.19
Relationship Closeness	0.23	1.00	0.24	0.23	0.15	0.27	0.23	0.13	0.18	0.12	0.20	0.17	0.11	0.11
Eagerness to Cooperate	0.37	4.09	1.00	1.67	0.24	1.67	1.67	1.13	0.20	0.21	0.49	0.29	0.21	0.17
Internal Dimension	0.49	4.44	0.60	1.00	0.20	1.00	2.33	0.23	0.47	0.23	0.71	0.78	0.21	0.23
Volumes of business	4.66	6.61	4.09	5.00	1.00	5.67	6.33	2.33	3.00	1.67	3.67	3.00	0.71	0.51
Internal composition	0.37	3.71	0.60	1.00	0.18	1.00	0.78	0.45	0.45	0.15	0.56	0.27	0.16	0.12
Quality System	0.37	4.44	0.60	0.43	0.16	1.29	1.00	0.23	0.23	0.16	1.22	0.56	0.11	0.11
Reputation	4.66	7.56	0.88	4.44	0.43	2.23	4.44	1.00	1.67	0.45	0.47	0.73	0.70	0.26
Customer Loyalty	2.03	5.53	5.00	2.14	0.33	2.23	4.44	0.60	1.00	0.51	0.49	1.78	0.21	0.21
Economic Status	6.18	8.22	4.85	4.44	0.60	6.61	6.18	2.23	1.96	1.00	2.11	2.33	0.78	0.51
Operational risk	0.72	5.00	1.40	1.40	0.27	1.80	0.82	2.14	2.04	0.47	1.00	0.73	0.23	0.16
Compatibility	1.36	5.87	0.33	0.33	0.33	3.72	1.80	1.36	0.56	0.43	1.36	1.00	0.23	0.29
Market knowledge	6.18	9.00	4.66	4.66	1.40	6.18	9.00	1.29	4.66	1.29	4.44	4.44	1.00	0.78
Specific Experience	5.40	9.00	4.44	4.44	1.96	8.22	9.00	3.86	4.66	1.96	6.18	3.46	1.29	1.00
Sum	**34.00**	**78.79**	**31.42**	**33.21**	**7.47**	**44.61**	**50.71**	**17.20**	**21.54**	**8.80**	**24.28**	**20.27**	**6.12**	**4.65**

TABLE 11 - PAIRWISE COMPARISON MATRIX FOR BUSINESS CATEGORY

This matrix has to be normalized. The weights of the criteria are then calculated as the average value of the criterion's grades. The following table also shows the Consistency Index, the Random Index and the Consistency Ratio. The concept is simple: if criteria A is better than criteria B, and criteria B is better than criteria C, A cannot be worst than C. Saaty (1980) defined that, for a comparison matrix to be valid, the consistency ratio has to be lower than 5% for a 3x3 one, 8% for a 4x4, and 10% for bigger ones.

Business	Strategic Alliances	Relationship Closeness	Eagerness to Cooperate	Internal Dimension	Volumes of business	Internal composition	Quality System	Reputation	Customer Loyalty	Economic Status	Operational risk	Compatibility	Market knowledge	Specific Experience	**Average value = Relative Weight**	**Consistency**
Strategic Alliances	0.03	0.06	0.09	0.06	0.03	0.06	0.05	0.01	0.02	0.02	0.06	0.04	0.03	0.04	**4.21%**	14.84076
Relationship Closeness	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	**1.10%**	14.57136
Eagerness to Cooperate	0.01	0.05	0.03	0.05	0.03	0.04	0.03	0.07	0.01	0.02	0.02	0.01	0.04	0.04	**3.23%**	14.76305
Internal Dimension	0.01	0.06	0.02	0.03	0.03	0.02	0.05	0.01	0.02	0.03	0.03	0.04	0.04	0.05	**3.05%**	14.61541
Volumes of business	0.14	0.08	0.13	0.15	0.13	0.13	0.12	0.14	0.14	0.19	0.15	0.15	0.12	0.11	**13.41%**	15.32402
Internal composition	0.01	0.05	0.02	0.03	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.03	0.03	**2.29%**	14.7425
Quality System	0.01	0.06	0.02	0.01	0.02	0.03	0.02	0.01	0.01	0.02	0.05	0.03	0.02	0.02	**2.36%**	14.64385
Reputation	0.14	0.10	0.03	0.13	0.06	0.05	0.09	0.06	0.08	0.05	0.02	0.04	0.11	0.06	**7.16%**	15.4444
Customer Loyalty	0.06	0.07	0.16	0.06	0.04	0.05	0.09	0.03	0.05	0.06	0.02	0.09	0.04	0.05	**6.18%**	14.96276
Economic Status	0.18	0.10	0.15	0.13	0.08	0.15	0.12	0.13	0.09	0.11	0.09	0.12	0.13	0.11	**12.12%**	15.32695
Operational risk	0.02	0.06	0.04	0.04	0.04	0.04	0.02	0.12	0.09	0.05	0.04	0.04	0.04	0.03	**4.90%**	15.45507
Compatibility	0.04	0.07	0.01	0.01	0.04	0.08	0.04	0.08	0.03	0.05	0.06	0.05	0.04	0.06	**4.69%**	15.0161
Market knowledge	0.18	0.11	0.15	0.14	0.19	0.14	0.18	0.07	0.22	0.15	0.18	0.22	0.16	0.17	**16.12%**	15.28934
Specific Experience	0.16	0.11	0.14	0.13	0.26	0.18	0.18	0.22	0.22	0.22	0.25	0.17	0.21	0.22	**19.17%**	15.29716
Sum	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	***100.00%***	

Consistency Index[46]	0.078532
Random Index	2.09
Consistency Ratio	3.76%

TABLE 12- NORMALIZED MATRIX WITH WEIGHT DEFINITION FOR BUSINESS CATEGORY

[46] The consistency is calculated diving the result of the multiplication between the comparison matrix and the weighs vectors, by the weight of the relative criteria. The Consistency Index is the average of each consistency. The Random index is defined by Saaty (1980) and depends on the number of indexes. The Consistency ratio is the ration between Consistency Index and Random Index.

In the following table the result of the evaluation can be seen. In particular, it can be found the relative and absolute weights of the second-level indexes and the weights of the first level categories.

Absolute Rank	Relative Rank	Criterion	*Relative Weight*	Absolute Weight
Business			***13.23%***	
10	**1**	Specific experience	**19.17%**	2.54%
14	2	Market knowledge	**16.12%**	2.13%
16	3	Volumes of business	**13.41%**	1.77%
17	4	Economic status	**12.12%**	1.60%
18	5	Reputation	**7.16%**	0.95%
19	6	Customer loyalty	**6.18%**	0.82%
20	7	Operational risk	**4.90%**	0.65%
21	8	Compatibility	**4.69%**	0.62%
22	9	Strategic alliances	**4.21%**	0.56%
23	10	Eagerness to cooperate	**3.23%**	0.43%
24	11	Internal dimension	**3.05%**	0.40%
25	12	Quality system	**2.36%**	0.31%
26	13	Internal Composition	**2.29%**	0.30%
27	14	Relationship closeness	**1.10%**	0.14%
Solution			***59.92%***	
1	**1**	Implementability	**26.66%**	15.97%
2	**2**	Project	**21.42%**	12.84%
3	**3**	Product/ service quality	**20.32%**	12.18%
5	**4**	Product features	**12.21%**	7.31%
6	**5**	Customer service	**11.48%**	6.88%
9	**6**	Technology adopted	**4.27%**	2.56%
13	**7**	Value Added Services	**3.63%**	2.18%
Capability			***22.00%***	
4	**1**	Flexibility	**52.34%**	11.51%
7	**2**	Financial status	**21.25%**	4.68%
8	**3**	Managerial Ability	**18.00%**	3.96%
9	**4**	Technology level	**8.40%**	1.85%
Green & Environment			***4.85%***	
12	**1**	Waste production	***50.00%***	2.43%
12	**1**	Green policies	***50.00%***	2.43%

TABLE 13 - FINAL WEIGHTS TABLE

5. METRICS

In order to have a usable tool, the definition of the selection criteria is not enough. In fact, the decision maker has to apply this tool to a series of possible suppliers, in order to have the desired comparison. During this practical usage of the model, the user has to rank the performances of the different suppliers referring to each single criterion. In this way, the points obtained in each criterion will be weighted and the final grade derived.

Unfortunately, the AHP methodology does not take into consideration how each single criterion will be evaluated, delegating that decision to the user.

In this paragraph, I will give the reference framework for the evaluation. In particular, each criterion can receive a grade from 0 (low) to 3 (high). The reason of this choice is that, using an even scale point, the decision maker is obliged to make a choice between "good" and "bad" as the "average" option does not exist.

Considering that the evaluation has to be performed by a potential customer, it is reasonable that a high number of information will be hidden. For this reasons, the different grade-levels of the criteria will be based either from a qualitative evaluation, or from a quantitative scale, based on the data obtained during the analysis of the market.

Since the evaluation is mainly based on qualitative data, it's not easy to give a consistent ranking based on a uniform metric. For this reason, I will provide some "Inquiry questions" in order to have a guideline through the compiling.

Note that this ranking process is applied only to the non-cost related dimensions. For the cost indexes, a different logic will be applied since they will be out of the AHP.

Criterion	Question to be answered	Points scale
	Business	
Strategic alliances	How many strategic alliances and/or partnerships the supplier has?	0. Zero alliances 1. One or two alliances 2. Three or four alliances 3. More than five alliances[47]
Relationship closeness	In the relationships that the supplier has, how close is the cooperation? Do they share core processes? Do they have frequent meetings? Do they have profit/loss sharing initiatives?	0. Not close at all 1. More open than close 2. More close than open 3. Very close

[47] An high number of alliances means that the company is recognized in the market and can leverage also on partner's strengths. The analysis of the market underlined that the average number of alliances is 2/3.

Eagerness to cooperate	Is the company willing to operate? Is it investing to create new cooperation? Is it willing to share client's strategy (e.g. growth)?	0. Not willing at all 1. More No than Yes 2. More Yes than No 3. Absolutely willing to
Dimension	How many employees are dedicated to dematerialization services?	0. From 0 to 10 1. From 11 to 20 2. From 21 to 30 3. More than 31
Volume of business	How much are the revenues related to the digitalization business unit?	0. From 0 to 1 Million € 1. From 1.1 to 5 Million € 2. From 5.1 to 15 Million € 3. More than 15.1 Million €
Employee composition	What is the percentage of technicians on the total number of employees dedicated to dematerialization services?	0. From 0% to 25% 1. From 75% to 100% 2. From 25 to 50% 3. From 50% to 75%[48]
Quality system	Does the supplier have a quality system implemented? Is the company ISO 9001 certified? Does the supplier have available records on the quality process?	0. No quality system 1. Medium low quality system 2. Medium high quality system 3. High quality system
General reputation	What is the company's reputation?	0. Very bad 1. Bad 2. Good 3. Excellent
Customer loyalty	Are the customers loyal to that supplier? How much is the average duration of supplier-customer relationships? Does the company have any initiative to increase customer loyalty?	0. Very bad customer loyalty 1. Bad customer loyalty 2. Good customer loyalty 3. Very good customer loyalty
Economic status	Is the company overall profitable? How is the overall economic status of the company?[49]	0. Company running a loss 1. Very low profitability 2. Average profitability 3. Highly profitable company
Operational risks	Does the supplier have experienced problems of data-missing? Are the internal data sufficiently protected? Is there any authorization procedure? Can it provide procedures on data security?	0. High risk 1. Medium high risk 2. Low risk 3. No risk
Compatibility	How is the compatibility between the two companies? Do they share the same view of the market? Do they have the same strategic objectives?	0. Not compatible at all 1. More No than Yes 2. More Yes than No 3. Completely compatible
Specific experiences	Does the supplier have previous	0. After 2011

[48] An high number of technicians will guarantee a more attention on the technical side of the solution. On the other side, an excess of technicians cannot cover the commercial part of the contract. The average percentage from the survey is 60% of technicians.

[49] A good indicator can be the Return On Investments of the company. The problem in this case is that the user evaluating the performances of the supplier in this criteria is external from the organization. Furthermore, the majority of the supplier are not listed companies, for this reason the acquisition of the balance sheet to find the data can be quite complex. Note that this index is a general evaluation of the economic status of the overall company, for the specific case, consider the "financial status" idex.

	experience in dematerialization services? For how long it have been operating in the dematerialization (E-invoicing and digital archiving market)?	1. Between 2010 and 2008 2. Between 2007 and 2006 3. Between 2005 and 2004[50]
Market knowledge	For how long has the company been in the market? (with no reference to the specific sector)	0. After 2011 1. Between 2010 and 2000 2. Between 1999 to 1990 3. Before 1989
Solution		
Value added service	How many of the following services are part of the supplier's offering? E-invoicing; Digital Archiving; Document management; EDI/WEB EDI; Digitalization; Channeling; Integration with banks; Integration with the suppliers; Delivery of the archive track	0. From 0 to 1 1. From 2 to 4 2. From 5 to 7 3. From 7 to 9
Customer service	How is the customer service? Is it available 24/7? Are they able in solving the problems? When calling, is there the possibility to talk directly to a technician? How long does it take for them to get to my company?	0. No customer service 1. Average bad customer service 2. Average good customer service 3. Good customer service
Product features	Is the product offered competitive? Does it answers to all clients' needs? Is there the possibility to include other future features?	0. Not competitive 1. More No than Yes 2. More Yes than No 3. Competitive product
Technology Adopted	Is the solution implementing the latest technology available? Are there any upgrades included?	0. Bad technology 1. Average bad technology 2. Average good technology 3. Good technology
Project	Does the implementation requires and Ad-hoc project? How long is the implementation? Is the project particularly expensive?	0. Bad project 1. Average bad project 2. Average good project 3. Good project
Product/ service quality	Is the product reliable? Is the service available when needed? Is there any previous case of malfunctioning?	0. Poor quality 1. More poor than good 2. More good than poor 3. Good quality
Implementability	Is it easy to implement the solution? Does the solution require specific customization? Does the IT landscape need any adaptation?	0. Difficult 1. More difficult than easy 2. More easy than difficult 3. Easy
Green & Environment		
Green/environmental policies	Do re-usage policies exist? Is the supplier part of some "green associations"?	0. No environmental policies 1. Few and limited policies 2. Internally implemented policies 3. Proactive behavior in environmental policies
Pollution/waste	Is the supplier measuring its emissions? Is	0. Low attention

[50] Consider that the official year of introduction of e-invoicing and digital archiving services is 2004.

production	it investing in emission reduction initiatives? What is the emission level of the supplier?	1. Medium low attention 2. Medium high attention 3. High attention
Capabilities		
Service flexibility	Is there any possibility of changing the service agreements after the signature of the contract? Can the terms of contract be changed during the relationship?	0. No flexibility 1. Medium low flexibility 2. Medium high flexibility 3. High flexibility
Specific technological competences	Is the technology utilized updated? Does the supplier adopt the latest technology available? How developed is the internal technology system? Do they develop the technology they offer?	0. Low technology competences 1. Medium low technology 2. Medium high technology 3. High technology competences
Financial status	Is the specific business unit healthy? Is it able to repay the debts? Is the company able to generate value?[51]	0. Bad financial status 1. Average bad 2. Average good 3. Good and healthy financials
Management ability	Is the management able to face ordinary as long as unexpected events? Is the management meeting the targets?	0. Law ability 1. Medium law ability 2. Medium high ability 3. High ability

[51] The same considerations done for the "economic status" can be applied here. The main difference is that this index has a more specific and detailed focus. In order to have an evaluation, relying of few data, a potential dimension can be the ratio between the revenues of the business unit and the number of employees dedicated to that unit (in this way the dimension factor is eliminated).

F. MODEL VALIDATION

In this chapter I will explain the methods through which the model has been validated. The validation process will not be referred only to the definition of the criteria's weights, but will include the whole process, from the definition of the indexes to the final AHP application.

The main source that guarantees the reliability of this research is the strict collaboration with the Observatory on E-Invoicing and Digital Archiving and its partners.

1. VALIDATION PROCESS

The model defined is nothing if not supported by a solid process and a consistent validation.

As regards the AHP, the need to satisfy some predefined requirements was underlined already by Saaty (1980) when developing the selection process. This is, though, not enough: the AHP is based on a set of indexes that must be representative and must fully explain the problem considered. For this reason the definition of the criteria has to have solid basis and must be validated by experts in the specific field.

Given the different steps included in this research, different validation processes can be distinguished according to the step considered.

The overview on the different validation steps can be seen in the following table:

Different validation steps

Process	Validation type
Definition of the indexes	- Literature basis
Selection of the indexes	- Cooperation with the experts of the Observatory on E-Invoicing and Digital Archiving - Cooperation with the Observatory's community
Definition of the weights	- Cooperation with the Observatory's community - Consistency check

In the following paragraphs I will explain why my personal model has to be considered valid.

2. DEFINITION AND SELECTION OF THE CRITERIA

The first relevant step of this research is the definition and the selection of the indexes on which to base the evaluation model.

The initial set of indexes was derived from the literature that, as can be seen in the methodology part, was composed by a relevant set of papers with medium-high impact factors. Once the indexes have been selected, I applied an equation to have an initial ranking. This equation was based on the importance of the papers referring to each specific index and the coherence with the application context.

One minor problem of this process was that it had a bias towards the most used criteria, giving higher importance to standard indexes and penalizing the most innovative or specific ones. For this reason I personally went through the whole set of indexes "saving" the most innovative or specific ones, basing the decision on the analysis of the market and on the dematerialization literature.

Of course my personal experience is not enough, for this reason I analyzed again, and validated, the indexes with the collaboration of the expert belonging to the Observatory on E-Invoicing and Digital Archiving of the Politecnico di Milano.

3. DEFINITION OF THE WEIGHTS

Once the criteria have been selected, in order to define the final model they have to be weighted. Note that this part is referred only to *Business*, *Solution*, *Capability* and *Green & Environment* categories, since for the Cost indexes don't need weighting (they are evaluated with the Total Cost approach).

The evaluation model selected is the Analytic Hierarchy Process: this is the most used in supplier selection works and it is commonly recognized as a reliable and valid tool[52].

The comparisons, on which the AHP is based, were obtained through a set of questionnaires sent to the partners of the Observatory. The reason for this choice is twofold:

- on one side, the community of the Observatory is composed by a set of companies that are equally distributed among all the sectors involved in the offering of dematerialization services (banks, service providers, printers, postal and EDI providers);
- on the other side, the community includes the most proactive and prepared actors, that are highly experienced and well prepared on these kind of services (thanks to the collaboration with the Observatory).

The fact that the companies involved are mainly belonging to the supply[53] side of the market, and the model should be used by the demand side, could be identified as a limitation. This could be reasonable for a mature market, but for the dematerialization one, we have to consider that:

- ✓ the market is not mature yet and there are few cases of organizations adopting E-Invoicing in the "pure" way;
- ✓ the majority of the companies are not enough prepared on dematerialization issues, and, in case of supplier evaluation, they can bias the weights towards the purchasing of traditional services.

Furthermore, the partners of the Observatory includes representative of different associations, among which: Consorzio CBI (representing the bank sector), Consorzio DAFNE (representing the pharmaceutical sector), EDIEL (representing the retailer sector), Assinform[54] and AssoSoftware (promoters of the diffusion of the Information Technology in Italy) and CNDCEC[55] (representing the accountants), that can represent the clients' side in the evaluation.

[52] For the complete explanation please refer to the methodology section.
[53] With "Supply side" I mean the companies offering the service, while the "demand side" is made of the companies purchasing the services.
[54] Associazione Italiana per l'Information Technology.
[55] Consiglio Nazionale dei Dottori Commercialisti ed Esperti Contabili.

Note that the fulfillment of the questionnaires is a further validation of the indexes selected: if a one was found not coherent, it would have received a very low grade, and its weight would make it irrelevant.

An additional critic that someone may arise is that, during the comparisons, each single company may answer in order to favorite its own company. This is not a real problem because, first, all the consistent matrixes showed more or less the same results, and second because the final matrix, the one on which the weights were based, derived from the average of each single contribution, eliminating any possible biases.

Another relevant issue is attributed to the definition of the weights. In fact the questionnaires have to be analyzed in order to derive the ranking: each single contribution has to be valid. For this reason I calculated the Consistency Ratio for each questionnaire, and eliminated the ones that did not respect Saaty's (1980) requirements[56].

This validation process was repeated again after the unification of the consistent questionnaires. In the following pages I will show the final matrixes, with the computation of the consistency.

Second-level categories:

-

Capability	Financial Status	Flexibility	Technology Level	Managerial Ability	**Average value = Relative Weight[57]**	**Consistency**
Financial Status	1	0.51	2.3	1	21.25%	4.03
Flexibility	1.96	1.00	6.33	3.67	52.34%	4.07
Technology Level	0.43	0.16	1.00	0.45	8.40%	4.02
Managerial Ability	1.00	0.27	2.24	1.00	18.00%	4.02
Sum	**4.39**	**1.94**	**11.91**	**6.11**	***100.00%***	
			Consistency Index[58]			0.01
			Random Index			0.90
			Consistency Ratio			**1.32%**

TABLE 14 - CAPABILITY FINAL MATRIX

[56] For more details please refer to the methodology part.

[57] Note that the results, before computing the weights, have to be normalized.

[58] The consistency is calculated dividing the result of the multiplication between the comparison matrix and the weighs vectors, by the weight of the relative criteria. The Consistency Index is the average of each consistency, minus the number of indexes, divided by the number of indexes minus one. The Random index is defined by Saaty (1980) and depends on the number of indexes. The Consistency ratio is the ration between Consistency Index and Random Index.

Solution	Customer Service	Value Added Services	Product features	Technology Adopted	Project	Implementability	Product/service quality	**Average value = Relative Weight**	**Consistency**
Customer Service	1.00	3.67	1.00	2.33	0.73	0.49	0.29	11.48%	7.11
Value Added Services	0.27	1.00	0.33	0.78	0.23	0.15	0.15	3.63%	7.18
Product features	1.00	3.01	1.00	4.33	0.33	0.51	0.73	12.21%	7.28
Technology Adopted	0.43	1.29	0.23	1.00	0.24	0.18	0.19	4.27%	7.18
Project	1.36	4.44	3.00	4.09	1.00	0.78	1.44	21.42%	7.35
Implementability	2.03	6.61	1.96	5.53	1.29	1.00	2.33	26.66%	7.37
Product/service quality	3.46	6.61	1.36	5.15	0.69	0.43	1.00	20.32%	7.33
Sum	**9.56**	**26.62**	**8.88**	**23.21**	**4.51**	**3.54**	**6.15**	***100.00%***	

Consistency Index	0.043
Random Index	1.32
Consistency Ratio	**3.24%**

TABLE 15 - SOLUTION FINAL MATRIX

Green & Environment	Waste Production	Green Policies	**Average value = Relative Weight**	**Consistency**
Waste Production	1	1	50%	2
Green Policies	1	1	50%	2
Sum	**1**	**1**	***100.00%***	

Consistency Index	NA
Random Index	NA
Consistency Ratio	**NA**

TABLE 16 - GREEN & ENVIRONMENT FINAL MATRIX

Business	Strategic Alliances	Relationship Closeness	Eagerness to Cooperate	Internal Dimension	Volumes of business	Internal composition	Quality System	Reputation	Customer Loyalty	Economic Status	Operational risk	Compatibility	Market knowledge	Specific Experience	**Average value = Relative Weight**	**Consistency**
Strategic Alliances	1.00	4.33	2.73	2.05	0.21	2.73	2.70	0.21	0.49	0.16	1.38	0.73	0.16	0.19	**4.21%**	14.84
Relationship Closeness	0.23	1.00	0.24	0.23	0.15	0.27	0.23	0.13	0.18	0.12	0.20	0.17	0.11	0.11	**1.10%**	14.57
Eagerness to Cooperate	0.37	4.09	1.00	1.67	0.24	1.67	1.67	1.13	0.20	0.21	0.49	0.29	0.21	0.17	**3.23%**	14.76
Internal Dimension	0.49	4.44	0.60	1.00	0.20	1.00	2.33	0.23	0.47	0.23	0.71	0.78	0.21	0.23	**3.05%**	14.62
Volumes of business	4.66	6.61	4.09	5.00	1.00	5.67	6.33	2.33	3.00	1.67	3.67	3.00	0.71	0.51	**13.41%**	15.32
Internal composition	0.37	3.71	0.60	1.00	0.18	1.00	0.78	0.45	0.45	0.15	0.56	0.27	0.16	0.12	**2.29%**	14.74
Quality System	0.37	4.44	0.60	0.43	0.16	1.29	1.00	0.23	0.23	0.16	1.22	0.56	0.11	0.11	**2.36%**	14.64
Reputation	4.66	7.56	0.88	4.44	0.43	2.23	4.44	1.00	1.67	0.45	0.47	0.73	0.70	0.26	**7.16%**	15.44
Customer Loyalty	2.03	5.53	5.00	2.14	0.33	2.23	4.44	0.60	1.00	0.51	0.49	1.78	0.21	0.21	**6.18%**	14.96
Economic Status	6.18	8.22	4.85	4.44	0.60	6.61	6.18	2.23	1.96	1.00	2.11	2.33	0.78	0.51	**12.12%**	15.33
Operational risk	0.72	5.00	1.40	1.40	0.27	1.80	0.82	2.14	2.04	0.47	1.00	0.73	0.23	0.16	**4.90%**	15.46
Compatibility	1.36	5.87	0.33	0.33	0.33	3.72	1.80	1.36	0.56	0.43	1.36	1.00	0.23	0.29	**4.69%**	15.02
Market knowledge	6.18	9.00	4.66	4.66	1.40	6.18	9.00	1.29	4.66	1.29	4.44	4.44	1.00	0.78	**16.12%**	15.29
Specific Experience	5.40	9.00	4.44	4.44	1.96	8.22	9.00	3.86	4.66	1.96	6.18	3.46	1.29	1.00	**19.17%**	15.30
Sum	**34.00**	**78.79**	**31.42**	**33.21**	**7.47**	**44.61**	**50.71**	**17.20**	**21.54**	**8.80**	**24.28**	**20.27**	**6.12**	**4.65**	***100.00%***	

Consistency Index	0.078532
Random Index	2.09
Consistency Ratio	**3.76%**

TABLE 17 - BUSINESS FINAL MATRIX

First- Level categories:

First level categories	Business	Solution	Capability	Green & Environment	**Average value = Relative Weight**	**Consistency**
Business	1.00	0.20	0.14	1.00	7.34%	4.00
Solution	5.00	1.00	3.00	7.00	53.53%	4.39
Capability	7.14	0.33	1.00	5.00	32.29%	4.24
Green & Environment	1.00	0.14	0.20	1.00	6.84%	4.14
Sum	**14.14**	**1.68**	**4.34**	**14.00**	***100.00%***	
			Consistency Index			0.064
			Random Index			0.9
			Consistency Ratio			**7.10%**

TABLE 18 - FIRST LEVEL FINAL MATRIX

G. FINDINGS AND CONCLUSIONS

In this chapter I will *analyze, with a critical eye, both the model development process and the results obtained from it.*

I will also explain why this model should be considered innovative and I will present some suggestions for future improvements.

1. INNOVATIVITY OF THE MODEL

The model is to be considered innovative for two main reasons.

The first one, and main reason, is the context of application. In fact, as highlighted in the literature review, no previous works on supplier selection for e-invoicing and digital archiving service have been performed until now.

The second one is how the evaluation methods have been combined. In fact, analysing the literature, it could have been noticed that different authors utilized more than one criteria selection models in their process. The final result was, though, a unique ranking applied to all the criteria, in order to have a unique global index. This approach could be misleading in this specific context, when the cost dimension has a particular importance and cannot be mixed with other types of evaluations. The methodology introduced in this research is to provide a global evaluation of the supplier, using an AHP, and compare the result with the cost of the solution calculated using the Total Cost approach.

2. APPLICABILITY OF THE MODEL

The model developed is a useful tool for the initial screening of the possible suppliers. It is thought, and it has to be applied, only to the selection of e-invoicing and digital archiving service providers. It has to be noticed that, usually, these kind of service are offered linked to others, such as document management. Even if this happens, the driver of the selection must be e-invoicing and digital archiving.

A further consideration to be done is that, given the importance of these kinds of decisions, the final choice cannot be left to an automated evaluator. For this reason, this model is a useful tool to support the decision maker, who will then have to take the final decision taking into consideration personal considerations.

3. FINDINGS AND COMMENTS

The double nature of the model (AHP and Total Cost) allows the derivation of different considerations according to the context of reference.

In the following paragraphs I will present and interpret the results obtained.

3.1 BUSINESS, SOLUTION, CAPABILITY AND GREEN & ENVIRONMENT DIMENSIONS

The application of the AHP process, and the definition of the weights for each criteria, underlined some trends, already depicted in the literature review, as long as new unpredicted patterns.

First of all, looking at the first level dimensions (categories level) it can be notices that the first position is occupied by *Solution* (59.92%). This result indicates that companies care more about the particular characteristics of the product offered, rather than the other ones. This fact can be understood considering the type of relationship that the client wants to install with its supplier: it can be considered as a purchasing-based relationship, where the main purpose it's the purchasing of a service or product, and not, for example, other strategic reasons, such as the development of a new product or the consolidation of the market position.

The second more relevant category is *Capability* (22%). This fact underlines the attention of potential clients to the specific performances of the supplier. The reason for this focus is easily derivable considering the nature of the processes involved: the customer is outsourcing the management of very sensitive data that, in case of errors, can lead to serious legal problems; it is a normal consequence that a stable and capable supplier is favourite.

The third and fourth places are occupied by *Business* (13.23%) and *Green & Environment* (4.85%). From this ranking, we can derive that companies do not care too much about the general characteristics of the company, as long as the solution offered is competitive and the company is experienced. Another confirmation of the little attention on Green aspect is the limited relevance of the issues measuring the environmental friendliness of the supplier.

Similar considerations can be done analysis the single indexes within each category.

Solution – The highest relative weights are dedicated to the implementation aspects of the solution: *Implementability* (26.66%) and *Project* (21.24%). The reason for this can be found among the adoption barriers highlighted in the literature review and confirmed by the analysis of the market. In particular, one of the main adoption barriers was that these kinds of services are strictly and

intimately linked to the every working processes: companies are very scared of implementing a big solution in just one single project. For this reason, it's clear why the dimensions referring to the duration of the project, and the easiness of implementation of the new solution are in the first two positions: companies want solutions that can be quickly introduced without big modifications of the already existing processes and facilities, nor too big economical commitments.

The following index, in level of importance, is referred to the product itself: *Product quality* (20.32%). This is quite normal if we consider that, as underlined before, the company is willing to set a relationship mainly for purchasing a service or a product, and, for this reason, the quality of the solution bought is of primarily interest. Medium low attention is, though, dedicated to *Product features* (12.21%) and *Customer service* (11.48%): the attention of the customers does not care too much about the specific features of the solution and the quality of the customer service. This can be understood considering that e-invoicing and digital archiving services are quite standard and, for this reason, potential clients are expecting to find the same features in every offering: the difference is, then, of the quality of the solution.

The least important dimension within the *Solution* category is *Value Added Services* (3.63%). This depicts that companies are not interested in the whole portfolio of the supplier and can be linked to the issue already stated when referring to Project and Implementability indexes: since customers are introducing few dematerialization solutions in several little steps, a wide offering, even if present, won't be exploited.

Capability – The second most important dimension is *Capability*. This category represents the specific performances of the potential supplier. In particular, clients are more focused on the *Flexibility* of their providers (53.34%). This can connected to the fear and the lack of preparation that clients may have: a company that wants to implement dematerialization solutions, but it's not sure of the outcomes of the project, may be more interesting in a flexible company that can follow its requests according to the results obtained. The recent growing attention on the financial status and solidity of the suppliers, identified during the literature review, is confirmed by the fact that *Financial status* and *Managerial ability* are in second and third position (21.25% and 18%): the recent big crisis affecting the whole economy has brought out the importance of having an healthy supplier, able of managing and making a living through unstable and unpredictable contexts, so to guarantee a continuous supply.

Little attention is dedicated to the supplier's internal *Technology level* (8.40%), probably because clients do not care about their supplier's internal capabilities as long as the service offered is competitive.

Business – Within the category measuring the general characteristics of the company, a primarily role is played by the experience of the supplier, both in general and specific terms: the *Specific knowledge* (19.27%) on dematerialization solutions, and the general *Market knowledge* (16.12%) are the first two positions. This is easily agreeable, and, combined with the results emerged from the *Capability* category, underlines the need of a reliable and experienced provider. Furthermore, the lack of experience of the majority of the potential clients, fosters the need of relying on the outsourcing fruition model, and, as a consequence, of the provider's own experience that is, for this reason, of primarily importance. The lack of client's experience explains also why *Reputation* (7.16%) is the fifth most important dimension (up to 14): companies are trying to fulfil this lack with the feedbacks of other organizations (consider also that *Customer loyalty* is the sixth position with 6.18%).

The second most relevant dimension within the *Business* category is, again, the attention on the stability aspects: *Volume of business* (13.41%) and *Economic status* (12.12%). If the reason for the second index is easily understandable, since it represents the overall economical status of the supplier, the motivations of the importance of the business volume criteria may not be trivial: high volumes in terms of, for example, invoices managed or pages archived, may be seen as a symptom a competitive offering, and, the linked high revenues, will favourite stability.

The remaining 25% of the total is equally distributed between 8 indexes, underling the little attention towards *Operational risks* (4.90%), *Compatibility* (4.69%), *Strategic alliances* (4.21%), *Eagerness to cooperate* (3.23%), *Internal dimension* (3.05%), *Quality system* (2.36%), *Internal Composition* (2.29%) and *Relationship closeness* (1.10%).

Green & Environment – The attention on the Green aspects of the business is still missing. Within this category, equal importance has been given to the *waste production* and *green policies* (50%).

3.2 COST DIMENSION

As regards the cost dimension, the analysis of the literature and the selection process identified 11 main criteria to be considered in the computation of the Total Cost. These criteria can be classified and the categories that follow.

- *Implementation costs* – Are the cost that the company has to sustain when decides to implement the solution. They usually appear *una tantum*, and are identifiable in *installation* and *training costs*.

- *Product cost* – These costs are the ones directly related to the service purchased. The company has to pay them according to the actual usage of the service, on a variable basis.

These costs are the *service price* and *other related costs* (for example cost of the printing or the digitalization).

- *Operative running costs* – These costs are necessary to run the operations. They are usually fixed (non dependent on the actual volumes) and with a yearly basis. The dimensions included in this group are *relationship costs*, *compliance costs*, *maintenance costs*, *cost of upgrades* and *minimum fee*. While the last 3 a quite easy to calculate, the first 2 are difficult to estimate, especially when no previous experience is available. To solve this problem, the company can rely on its own experience of relationships in other contexts or ask for feedbacks to some partners.

- *Payment terms* – These are not real costs, but are consideration that the decision maker has to make when evaluating the offers. The first one is referred to the possibility to have any discounts depending on the volumes, while the second one includes some contract clause that could turn out to be cost for the company (for example some penalties).

4. LIMITS OF THE MODEL

The model defined is particularly useful for the cases already defined. On the other side, some limitations are also present. Here I will explain the more relevant ones, divided according from where they derive.

- *Selection criteria* – the selection criteria are strictly linked to the specific context and cannot be used for another one. Furthermore, the process of deriving those indexes is based on the literature, so is quite past oriented. Also the tool to select the best ones favorites the most used ones, putting in aside the new and innovative ones → I tried to overcome this limitation developing a new and personal analysis of the supply market and checking all the indexes with reference to the specific application context.
- *Evaluation methods* – some limitations are connected to the selection processes themselves.
  - *AHP* – This part of the model includes all the limitations of the AHP: compensation of bad scores with good ones, and hypothesis of independency among the criteria. Furthermore, as already highlighted before, one weak point of the AHP is the definition of how the performance of the supplier for each specific criterion has to be measured → In order to partially overcome this consideration, I developed a series of qualitative and quantitative evaluating scales: for the qualitative part I proposed a set of "inquiry questions" in order to lead the evaluation, while for the quantitative

ones, where possible, I used the data acquired from the analysis of the market to provide a ranking.

- *Total Cost* – The calculation of the cost of the solution reflects the drawback of the Total Cost approach that is the hard task to consider all the types of costs. Another disadvantage of the Total Cost is that it calculates only the cost dimensions: this point has been solved applying another methodology (the AHP) to the non-cost related dimensions.

- *Weights definition* – the pairwise comparison is made through a questionnaire sent to the market players. The final comparison is the average value derived from the single comparisons. The best way to derive the overall ranking should have been a Delphi method among the participants instead of a simple average value.
- *Time applicability* – the last point to be considered is that, during the comparisons, the decision maker is referring to the particular historical moment of 2012. The same comparison done in a period of a more stable economy, with an overall growth, will for sure lead to different results. For this reason, this model is applicable to a period with the same overall economic conditions.

5. FUTURE RESEARCHES

This research wants to be the beginning of a more structured attention on supplier selection for dematerialization services. For this reason, a possible future improvement is to enlarge the applicability of the model to other types of dematerialization services, starting from EDI and document management.

Secondly, the same selection criteria can be evaluated by companies of the demand part in order to perform a gap analysis between the perception of the supply and the real needs of the demand.

H. EXAMPLE OF APPLICATION

In this chapter I will provide one fast example of application of the model for three possible made up companies.

1. COMPANIES AND PERFORMANCES

Supplier 1, Supplier 2 and Supplier 3 are three possible service providers for e-invoicing and digital archiving solutions. Company ABC wants to rank them and, since they have no previous experience, they decided to apply this model in order to have a guideline on which to basis its decision.

The first step is to evaluate the performances of each single supplier in all the criteria.

Even at a first glance, it can be noticed that Supplier 1 receives higher ranks for the dimension *Business*, meaning that it has solid background and overall good performances at company level; it has medium values for the *Solution* and *Green & Environment* part, but low grades for the *Capability* assessment. On the other side, Supplier 2 has a very competitive *Solution*, medium high level for *Green & Environment* and for the *Capabilities*, and low grades for the general *Business* performances. The final candidate, Supplier 3, receives medium ranks in all the dimensions.

The complete list of the performances can be seen in the following table.

Category	Criterion	Weight	Supplier 1	Supplier 2	Supplier 3
Business (13.25%)	Compatibility	4.69%	3	2	2
	Customer loyalty	6.18%	2	1	3
	Eagerness to cooperate	3.23%	3	2	1
	Economic Status	12.12%	2	3	2
	Internal composition	2.29%	2	2	2
	Internal dimension	3.05%	3	1	3
	Market knowledge	16.12%	3	2	2
	Operational risk	4.90%	2	0	1
	Quality system	2.36%	3	2	2
	Relationship Closeness	1.10%	2	0	2
	Reputation	7.16%	3	1	0
	Specific Experience	19.17%	3	2	2
	Strategic Alliances	4.21%	3	2	1
	Volume of business	4.69%	2	1	3
Solution (59.92%)	Customer service	11.48%	2	3	2
	Implementability	26.66%	2	3	2
	Product features	12.21%	1	2	2
	Product/service quality	20.32%	3	3	1
	Project	21.42%	2	2	3
	Technology adopted	4.27%	1	3	1
	Value Added Services	3.63%	3	2	2
Capability (22.00%)	Financial status	21.25%	1	2	3
	Flexibility	52.34%	3	3	2
	Managerial ability	18.00%	1	2	3

	Technology level	8.40%	2	2	3
Green & Environment (4.85%)	Waste production	50.00%	2	0	3
	Green policies	50.00%	2	1	2

TABLE 19 - EXAMPLE OF CRITERIA EVALUATION

Weighting the performances, the results are listed in the following table.

	Supplier 1	**Supplier 2**	**Supplier 3**
Business	2.05	1.70	1.96
Solution	2.07	2.63	1.97
Capability	2.13	2.52	2.48
G&E	2.00	0.50	2.50
Total	**2.08**	**2.38**	**2.11**

TABLE 20 - EXAMPLE OF OVERALL RANKING

The previous dimensions can also be represented in a graphical way:

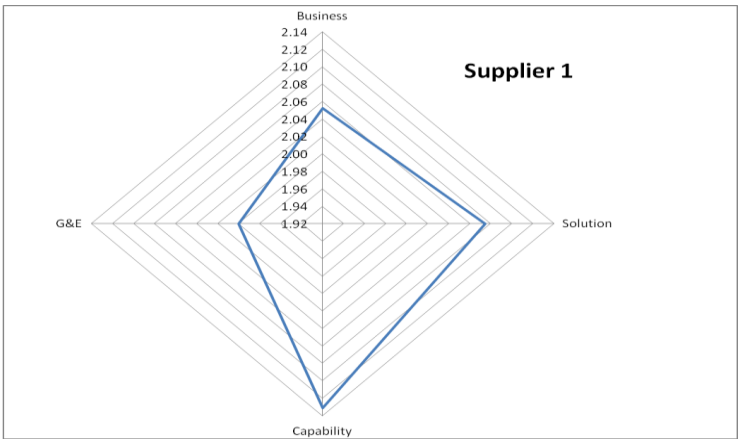


TABLE 21 - EXAMPLE OF EVALUATION FOR SUPPLIER 1

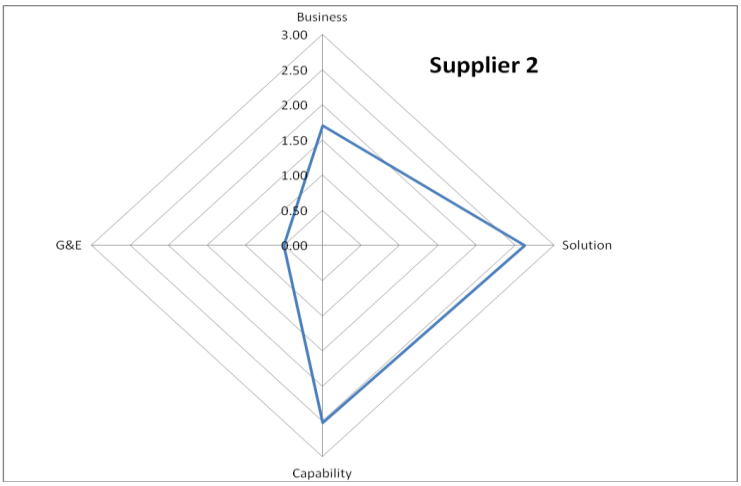


TABLE 22 - EXAMPLE OF EVALUATION FOR SUPPLIER 2

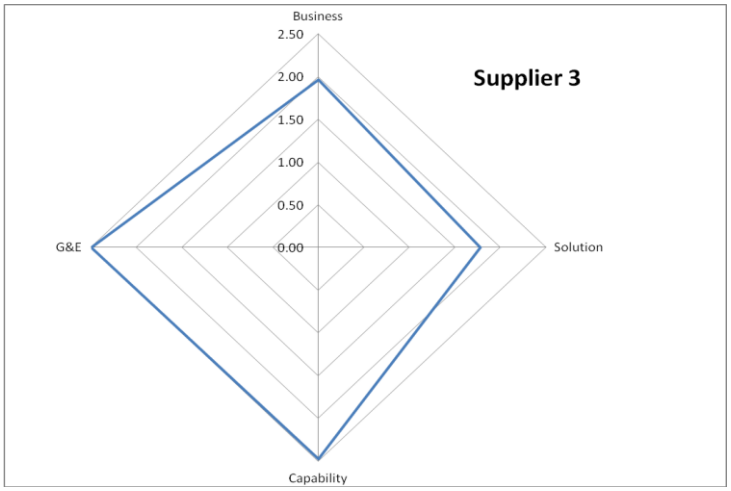


TABLE 23 - EXAMPLE OF EVALUATION FOR SUPPLIER 3

Looking only at this evaluation, Supplier 2 seems the best choice, but we didn't take into consideration the cost dimension.

2. COST ASSESSMENT

In order to evaluate the cost of the solution, the user decided to apply the Total Cost model. In particular the choice was to calculate the costs of the solution for the first two years of operations.

In particular the data found are as follows. Note that the estimated volume of e-invoices and documents brought in digital archiving is 1 Million Pages/Year. Note also that the "*Discount flexibility*" is included in the price.

Category	Costs indexes	Supplier 1	Supplier 2	Supplier 3
Implementation costs	Installation & Customization	€ 5,000.00	€ 2,000.00	€ 7,000.00
	Training costs	€ 1,000.00	€ 0.00	€ 0.00
Product cost	Price (€/page)	€ 0.02	€ 0.04	€ 0.02
	Other costs	NA	NA	NA
Operative running costs	Relationship costs	€ 1,000.00	€ 1,000.00	€ 1,000.00
	Maintenance costs	€ 0.00	€ 0.00	€ 0.00
	Cost of upgrades	€ 2,000.00	€ 1,000.00	€ 3,000.00
	Minimum fee	NA	NA	NA
Payment terms	Terms of contract	No particular clauses		

TABLE 24 - EXAMPLE OF COST INDEXES

The total cost can then be calculated as follows. Note that, since we are considering the first 2 years of operations, the product and operative running costs have to be doubled.

	Supplier 1	Supplier 2	Supplier 3
Implementation costs	€ 6,000.00	€ 2,000.00	€ 7,000.00
Product cost	€ 20,000.00	€ 35,000.00	€ 15,000.00
Operative running costs	€ 3,000.00	€ 2,000.00	€ 4,000.00
Payment terms	€ -	€ -	€ -
Total cost	€ 52,000.00	€ 76,000.00	€ 45,000.00

TABLE 25 - EXAMPLE OF TOTAL COST CALCULATION

From this computation we can see that Supplier 2 is also the most expensive option.

3. COST VS PERFORMANCE ANALYSIS

The innovativity of this model is that the results can be compared considering the trade-off between costs and performances.

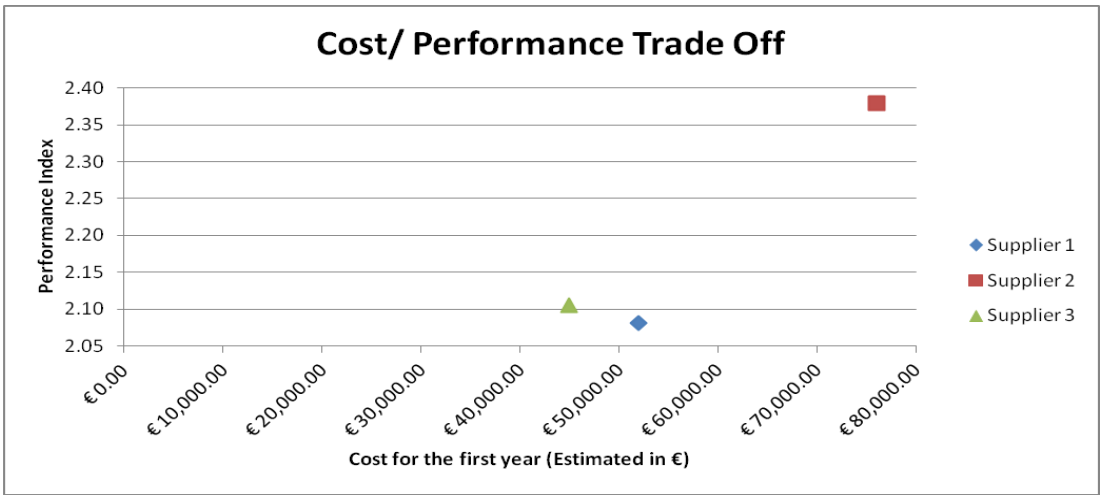


TABLE 26 - EXAMPLE OF COST/PERFORMANCE TRADE-OFF

Simply looking at the graph, some useful considerations can be made.

- Supplier 2 is the most expensive one, but the higher cost is well supported by better performances.
- Even though Supplier 3 has lower price and higher performances than Supplier 1. For this reason the decision maker can decide to eliminate a priori Supplier 1 from the competition.
- The difference in performance between Supplier 3 and Supplier 2 is the 15% in favor of Supplier 2. On the other side though, the offer of Supplier 3 is the 40% lower than the one of Supplier 2.

For these reasons, the best choice seems Supplier 3.

At this point, is the role of the decision maker to analyze the results, put in place its personal considerations, and take the final decision.

I. ANNEXES

Index of the Annexes

1. History of supplier selection – Complete list of the indexes.....169
2. Modern works on supplier selection – Complete list of the indexes.....170
3. Complete interview's structure.....179

1. HISTORY OF SUPPLIER SELECTION – COMPLETE LIST OF THE INDEXES

Comparison between different contributions. *Sources:* (Dickson, 1966; Pan, 1989; Ellram, 1990; Weber, 1991; Choi & Hartley, 1996)						
Main category	**Criteria**	**Dickson 1966**	**Pan 1989**	**Ellram 1990**	**Weber 1991**	**Choi 1996**
Product/service	Price	√	√		√	√
	Quality	√	√		√	√
	Repair service	√				
	Packaging Ability	√				
	Training aids	√				
	Service constrains		√			
	Delivery	√				√
	Warranties and claim policies	√				
	Reciprocal arrangements	√				
	After sale support					√
	Reliability					
	Flexibility					
Financials	Performance and economical history	√		√		√
	Financial position	√		√		√
Technology	Technical capability	√		√	√	√
	Speed in development			√		
	Future technology			√		√
	Set up time					√
Management and operation	Operating Controls	√				
	Management and organization capabilities			√	√	
	Desire for business	√				
	Labour relations record	√				
	Production facilities and capacity	√			√	
	Procedural compliance	√				
	Attitude	√				
	Amount of past business	√				
	Communication system	√				√
	Strategic fit			√		
Company's reputation	Feeling of trust			√		
	Reputation and position in industry	√		√		√
	Impression	√				
Other	Geographical location				√	
	Safety record of the supplier			√		√

Ranking of 3pl selection factors. Source: www.iwla.con and (Aguezzoul, 2007)			
Selection factors	**2003**	**1999**	**1994**
Price	1	4	11
Reliability	2	2	2
Service quality	3	1	1
On-time performance	4	3	3
Cost reduction	5	6	14
Flexibility and innovation	6	5	7
Good communication	7	10	4
Management quality	8	7	8
Location	9	12	13
Customize service	10	13	9
Speed of service	11	8	6
Order cycle time	12	9	10
Easy to work with	13	16	12
Customer support	14	11	5
Vendor reputation	15	15	15
Technical competence	16	18	19
Special expertise	17	14	16
System capabilities	18	17	17
Variety of available services	19	20	20
Decrease labor problems	20	23	22
Personal relationships	21	19	18
Decreased asset commitment	22	22	23
Early modification of disruptions	23	21	21
Increase competition	24	24	24
Global capabilities	25	25	25

2. MODERN WORKS ON SUPPLIER SELECTION – COMPLETE LIST OF THE INDEXES

Jharkharia & Shankar (2007) selection criteria description	
Criterion	**Description and relevance**
Compatibility with the users	It refers to the ability of the user and the provider and their support systems to work together in close coordination to achieve some common objectives. It may be classified in terms of the attributes of business process, cultural fit, technology capability, characteristics of other service providers of the user, etc.
Cost of service	It refers to the total cost of logistics outsourcing, which should be minimum.
Quality of service	Quality of the provider includes many aspects such as on-time delivery, accuracy of order fulfillment, frequency and cost of loss and damage, promptness in attending customers' complaints, commitment to continuous improvement, etc.
Reputation of the company	The reputation of a provider refers to the opinion of the people about how good they are in satisfying the needs of the customer. The reputation of a provider plays a major role in its selection. This is more

	relevant in the initial screening of the providers.
Long-term relationship	Long-term relationships, which include shared risks and rewards, ensure cooperation between the user and the provider. It also helps in controlling the opportunistic behavior of providers.
Performance measurement	Provision of periodic evaluation of the performance of the provider enables the two parties to identify the gaps in service. On-time shipments, inventory accuracy, shipping errors, reduction in cash-to-cash cycle, logistics cost reduction, and reduction in customers' complaints may be used as the most important performance measures in logistics outsourcing.
Willingness to use logistics manpower	The willingness of the provider to retain some of the user's logistics employees, who would otherwise become unemployed after the outsourcing contract, avoids any chance of sabotage. It also improves the goodwill between the user and the provider.
Flexibility in billing and payment	Flexibility in billing and payment conditions increases goodwill between the user and the provider.
Quality of management	Able management of the provider may not only provide good service to the user but may also foster a long-term relationship between the user and the provider.
Information sharing and mutual trust	Mutual trust-based information sharing between the user and the provider is necessary not only for the continuance of the agreement but also for the continuous improvement of the service.
Operational performance	A good operational performance of the provider is reflected by measures such as delivery performance, performance-monitoring capability, statistical data reporting to the user, fault diagnosis capability, detailed accounting information, system security, responsiveness, confidentiality of sensitive data, etc.
Information technology capability	The advanced IT capabilities of a provider help in reducing uncertainties and inventory level. In some cases, the providers may allow the users to take advantage of their advanced IT capabilities. In such cases, the user companies need not invest in advanced IT capabilities just for the sake of tracking of goods and raw materials.
Size and quality of fixed assets	It helps in good operational performance. Availability of quality assets (such as air-conditioned warehouses and vehicles), which suit the needs of the user, is a plus point for the provider.
Experience in similar products	Prior experience of the provider in the product line of user is the added advantage to the user.
Delivery performance	Two dimensions of DP, namely "speed" and "reliability", are important for the satisfaction of the user.
Employee satisfaction level	It is important as the presence of dissatisfied employees at the provider's end may lead to strike, lockouts, sabotage, and other such unwanted activities, which may adversely affect the logistics operations.
Financial performance	A sound financial performance of the provider ensures continuity of service and regular upgrading of the equipments and services, which are used in logistics operations.
Market share	The market share of the provider reflects its financial performance, customer satisfaction, and reputation.
Geographical spread and range of services provided	Wide geographic spread and range of services offered by the provider are desirable as these create enhanced access to market and many more avenues to the user. Large GS and RS offered by the provider may also enable the user to save some money on distribution and marketing of the product.

Risk management	It is the capability of the provider to address any unforeseen problem. It is needed to ensure the continuity of the services.
Surge capacity of provider	It becomes important if (due to sudden rise in demand of product) there is a rise in the logistics needs of the user.
Clause for arbitration and escape	In the long run the possibility of a dispute between the user and the provider cannot be denied. Therefore, provision of a CAR, which is acceptable to both the parties, is necessary.
Flexibility in operations and delivery	Flexibility in operations and delivery may enable the user to give customized service to its customers, particularly in special or non-routine requests.

Chang, et al. (2010) selection criteria description		
Category	**Criterion**	**Description**
Capacity of service	Service, relationship, and support of contractors	After-sales services and completion of the system with international standards.
	Completeness of system document, manuals, and process improvement capability	Detailed, simple and complete description of the system document. Quality assurance compliant.
External evaluation	Reputation	External personnel's evaluation of companies.
	Knowledge on the clients' industry	Understanding of the client's industry.
Capacity of professional skills	Property, quality and reliability of products	Respect of standard certification according to user's needs.
	Capacity for system integration	Integrate various isolated information systems (middleware and integration software).
	Information security techniques	Maintain a secure system (firewall, data encryption, anti-virus, and logins).
	Capacity for research and development	Create and assimilate new knowledge.
	Development tools of the system	The programming language used (Visual Basic, Java, ASP and C++)
	Software and hardware capacities	Provision of various software programs used by the company.
Capacity of operation	Maintenance of business confidentiality	Provision of confidentiality in business transactions and corresponding documents.
	Organizational resources	Overall resources within the company.
	Capacity for specific project management items	Plan and execute specific projects.
	Stability of financial affairs	Level of quality of financial performances.
	Enterprise culture	Vision and management idea of the top executives.
	Flexibility of contractors in relation to the deadline	Possibility to change the contract after the signature is put.
	Capacity of employees	Employee's working efficiency.
	Lawsuits with clients	Presence of previous lawsuits with some clients.

	Previous cooperation with proprietors	Whether there is or not any previous relationship with the client.

Li, et al. (2012)		
Weight	**First-level indices**	**Second-level indices**
0.2	Management success	The ratio of managerial staff ; organizing ability; coordination ability; rules and regulations ; input-output efficiency; equipment utilization
0.25	Business strength	Configuration and scale of service equipment; technological innovation; financial situation; representative performance for 5 years; structural features of the professional technical staff
0.3	Service quality	Information construction situation; information receiving and processing rate; convenience of information exchange and communication; coverage and application of Network Resources; service quality; customer satisfaction
0.25	Business growth	Enterprise scale; management concept; comprehensive quality of employees

Sonmez & Moorhouse (2010)			
Rank	**Factor**	**Criterion**	**Description**
1	Product feature	Meet client needs	The ability of the provider to customise the solution to our needs
2		Ability to change thinking	The ability of the trainer to challenge our thinking
3		Bring added value	The ability of the organisation to bring added value
4	Ability to measure training effectiveness	Training effectiveness	Ability to measure the training effectiveness
5	Experience	Presentation	The gravitas and personal presentation of the trainer
6		Offer real experience	They can offer real world experience and anecdotes
7	Ability to measure training effectiveness	Return on investment	Evidence of a tangible return on investment (ROI)
8	Knowledge and understanding	Knowledge of industry	The provider reveals their knowledge of our industry sector issues
9	Product feature	Flexibility	That the provider has sufficient trainers to offer flexibility around your scheduling dates
10	Experience	Personal Assessment	Personal assessment of the trainer delivering a training session
11		Projects completed	Evidence of the number of similar projects completed successfully
12		Effective solution	The training has been used by many people and proved to be effective - a “tried and tested” solution

13	Relationship	Successful relationships	Previous experience of a successful relationship
14		Personal Contact	There is personal contact with the one who delivers the training
15	Knowledge and understanding	Demonstrated good knowledge	The provider demonstrates a good knowledge of our company via research
16		Demonstrate cultural understanding	The provider demonstrates an understanding of our cross-cultural challenges
17	Product value	Help business case	The training organisation helps us to build the business case internally
18	Product feature	Range products	The range of training products available
19	References	Successful stories	Examples of success stories from other companies
20	Product feature	Opportunity to test	The opportunity to participate in a pilot or test session
21		Latest innovative methods	The training features the latest and most innovative methods
22		Train internal personnel	The opportunity to train internal personnel to deliver the training
23	Other	Recommend	Recommendation from an internal user
24	References	References	Having access to current clients for a personal reference
25	Product feature	Options	The range of training options
26	Relationship	Personal relationship	There is a strong personal relationship with the training provider
27	Internal capability	Consistency	That there is consistency in training delivery and materials across multiple countries
28	Reputation	Time in Bus	The provider's length of time in business
29	Internal capability	Language	The provider can offer an option to train delegates in their local language
30		Intellectual Property	The provider owns their own Intellectual property on training materials
31	Organization capabilities	Personnel	Depth of personnel – the number of trainers employed by the company
32	Reputation	Qualifications of trainers	The qualification of the trainer (MBA, PhD etc.)
33		Membership	Corporate membership of professional and industrial associations
34		Clients	An indication of their top five clients by revenue
35		Publications	The provider has published books in their subject area
36	Organization capabilities	Size	The size of the company, measured by annual revenue
37	Product value	Lowest price	The quoted price is the cheapest of all potential suppliers

Vinodh et al. (2011) selection criteria					
Category	*Business Improvement*	*Extent of fitness*	*Quality*	*Service*	*Risks*
Criteria	Reputation of industry	Sharing of experience	Low defect rate	On time delivery	Supply constrains
	Financial Strength	Flexible practices	Commitment to quality	Quick responsiveness	Buyer supplier constraint
	Managing ability	Diversified Customers	Improved process capability	Supplier capacity	Supplier profile
	Organization Customers				

Sevkli, et al. (2007) selection criteria	
Category	**Criterion**
Performance assessment	Shipment quality
	Delivery
	Cost analysis
Human Resources	Number of employees
	Organizational structure
	Training
	Number of technical staff
Quality system assessment	Management commitment
	Inspection
	Quality planning
	Quality assurance
Manufacturing	Production capacity
	Predictive and preventive maintenance
	Lead-time
	Transportation-storage and packaging
	Up-to-date techniques and equipment
	New product development
Business criteria	Reputation
	Geographical location
	Price
	Patent
	Technical capability
Use of IT	EDI
	Internet
	RFID

Chou & Chang (2008) selection criteria		
Rank	**Category**	**Criterion**
7	Cost	Unit price
4		Cost reduction
10	Quality	Interval rejection rate
1		Customer rejection rate
6	Delivery	Lead time
5		Flexibility
2	Organizational culture and strategy	Management capability
9		Strategic fit
8	Technical capacity	Innovation
3		Technical problem-solving

Lam, et al. (2010) selection criteria		
Category	**Criterion**	**Referred to**
Cost	Total cost	Narasimhan (1983); Bharadwaj (2004); Florez-Lopez(2007); Wang (2008)
	Price stability	
Quality	Failures prevention	
	Appearance and functions	
Service	On time delivery	
	Technical assistance & support	
	Cooperation & communication	
Buyer supplier relationship	Buyer supplier relationship	
Assurance of supply	Capacity	
	Reliability	Hadikusumo, et al. (2005)
	Flexibility	Kong, et al. (2004)
Payment terms	Payment terms	Hadikusumo, et al. (2005); Ng & Li (2006)
Past performance	Past record	Hadikusumo, et al. (2005)
	Reputation	

Yen & Chuang (2011) environmental selection criteria				
Category	**Criteria**		**Category**	**Criteria**
Green image	Customer's purchase or not		Pollution treatment cost	Water pollution treatment cost
	Green customer's market share			Energy consumption costs
Product recycling	Reverse logistics			Air pollution treatment cost
	Recycling rate			Chemical wastes treatment cost
Green design	Renewable product design of suppliers			Solid waste treatment costs
	Recycling product design of suppliers		Environmental performance assessment	Cadmium content
Green supply chain management	Environmental protection plans			Mercury content
	Environmental protection			Led content

	policies			
	Passing ISO 14000 verification			Air pollution

Bai & Sarkis (2010) selection criteria					
	Category	**Criterion**		**Category**	**Criterion**
Strategic performance	Cost	Low initial price	Environmental performance	Resource consumption	Consumption of energy
		Compliance with cost analysis system			Consumption of raw material
		Cost reduction			Consumption of water
		Compliance with sectorial price behaviour		Pollution production	Production of polluting agents
	Quality	Conformance to specification			Production of toxic products
		Consistent delivery			Production of waste
		Quality philosophy	Internal social criteria	Employment practices	Disciplinary and security practices
		Prompt response			Employee contracts
	Time	Delivery speed			Equity labor sources
		Product development time			Diversity
		Partnership formation time			Discrimination
	Flexibility	Product volume changes			Flexible working arrangements
		Short set-up time			Job opportunities
		Conflict resolution			Employment compensation
		Service capability			Research and development
	Innovativeness	New launch of products			Career development
		New use of technologies			Health and safety incidents
Organizational performance	Culture	Feeling of trust			Health and safety practices
		Management attitude for the future	External social criteria	Local communities influence	Health
		Strategic fit			Education
		Top management compatibility			Housing
		Compatibility among levels and functions			Service infrastructure
		Suppliers organzational structure and personnel			Mobility infrastructure
	Technology	Technological capability			Regulatory and public services
		Assessment of future manufacturing capabilities			Sensory stimuli
		Suppliers speed in development			Supporting educational institutions
		Suppliers design capabiliy			Security
		Techncial capability			Cultural properties
		Current manufacturing facilities			Economic welfare and growth
	Relationship	Long term relationship			Social cohesion
		Relationship closeness			Social pathologies
		Communication openess			Grants and donations
		Reputation for integrity			Supporting community

					projects
Environmental practices	Pollution controls	Remediation			Procurement standard
		End-of-pipe controls			Partnership screens and standards
		Product adaptation			Consumers education
		Process adaptation		Other stakeholders influence	Decision influence potential
	Environmental management system	Establishment of environmental commitment and policy			Stakeholder empowerment
		Identification of environmental aspects			Collective audience
		Planning of environmental objectives			Selected audience
		Assignment of environmental responsibility			Stakeholder engagement
		Checking and evaluation of environmental activities			

Ertugrul & Karakasoglu (2009) financial performance criteria					
Category	**Criterion**	**Weight**	**Category**	**Criterion**	**Weight**
Liquidity ratios	Current ratio	0.190	Activity ratios	Account receivables ratio	0.196
	Quick ratio	0.370		Inventory turnover ratio	0.197
	Cash ratio	0.440		Current assets turnover ratio	0.235
Profitability ratios	Net profit margin	0.707		Total asset turnover ratio	0.196
	Return on equity	0.293		Account payable turnover ratio	0.177
Growth Ratios	Sales growth	0.381	Financial leverage	Debt ratio	0.290
	Operating Profit growth	0.482		Shareholder's equity / assets	0.288
	Shareholders' equity growth	0.137		Fixed assets / shareholder's equity	0.235
	Assets growth	0.000		Fixed assets / long term debt	0.247

3. COMPLETE INTERVIEW'S STRUCTURE

Interview's Structure – Complete interview		
General Objective	➢ Understand the business model and the value proposition ➢ Define the services offered and how they are articulated ➢ Know number and typology of the clients	
Issue	**Question**	**Objective**
General information	• Company's history • Area of origin (bank, software house, …) • Revenues and number of employees • Collaborations and partnerships	Classify the company in order to allow a coherent comparison among its competitors.
Clients	• Number • Dimension (Big >250, PMI, Micro <10 employees) • Client's sector • Growth trend in terms of number and volumes	Understand the number and type of clients, their dimension and sector as long as the evolution trend.
Services	• Evolution of the offering (from the original core business) • Services offered and repartition on revenues (Digital Archiving, E-invoices, digital fingerprint, document management, Integration with the bank sector, integration with the value chain, EDI, Postal service). • Future trend forecasted and planned. • Service fruition model (In-House, Outsourcing, Web platform, EDI).	Define the company's offering and its evolution (past and future). Define the most commonly offered services and how they are proposed.
Technological infrastructure	• Initial investment • Technology internally available • Time needed for the development of the offering	Dimension the initial investment to start up a similar company, both in terms of time and costs.
Client management	• Types of document managed (E-invoices received and issued, accounting books, …) and percentage of each • Pricing logic (per page, standard price or project logic) • How to get to new clients (direct contact or through partnerships) • Target clients	Define the policies adopted with the clients, the marketing approach and the target of the offering.
Internal composition	• Number of employees dedicated to digital archiving and e-invoices • Percentage of technicians and commercials.	Understand the internal composition of the workforce.

J. REFERENCES

REFERENCES

Aamodt, A. & Plaza, E., 1994. Case-Based Rasoning: Foundational Issues, Methodological Variations, and System Approaches. AI Communications, pp. 39-59.

Aguezzoul, A., 2007. *The third party logistics selection: a review of literature.* Instanbul, Turkiye, s.n.

Aissaoui, N., Haouari, M. & Hassini, E., 2007. Supplier selection and order lot sizing modelling: A review. *Computer and Operations Research,* pp. 3516-3540.

Amid, A., Ghodsypour, S. & O'Brien, C., 2006. Fuzzy multiobjective linear model for supplier selection in a supply chain. *International Journal of Production Economics,* pp. 394-407.

Amin, S. & Razmi, J., 2009. An integrated fuzzy model for supplier management: A case study of ISP selection and evaluation. *Expert Systems with application,* pp. 8639-8648.

Amin, S., Razmin, J. & Zhang, G., 2011. Supplier selection and order allocation based on fuzzy SWOT analysis and fuzzy linear programming. *Expert Systems with Applications,* Volume 38, p. 334–342.

Andersson, D. & Norrman, A., 2002. Procurement of logistics services - A minute work or a multy-year project?. *European Journal of Purchasing and Supply Chain Management,* pp. 3-14.

Araz, C., Ozfirat, P. & Ozkarahan, I., 2007. An integrated multicriteria decision-making methodology for outsourcing management. *Computers & Operations Research,* Volume 34, p. 3738 – 3756.

Aydin, S. & Kahraman, C., 2010. Multiattribute supplier selection using fuzzy analytic hierarchy process. *International Journal of Computational Intelligence Systems,* 3(5), pp. 553-565.

Bai, C. & Sarkis, J., 2010. Integrating sustainability into supplier selection with grey system and rough set methodologies. *International Journal of Production Economics,* Volume 124, pp. 252-264.

Barratt, M. & Oliveira, A., 2001. Exploring the experience of collaborative planning initiatives. *International Journal of Physical Distribution & Logistics Management,* 31(4), pp. 266-289.

Bhatti, R. S., Kumar, P. & Kumar, D., 2010. Analytical modeling of third party service provider selection in lead logistics provider environments. *Journal of Modelling in Management,* 5(3), pp. 275-286.

Bhutta, S., K. & Huq, F., 2002. Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches. *Supply Chain Management: An international Journal,* pp. 126-135.

Billhardt, H., Hermoso, R., Ossowski, S. & Centero, R., 2007. Trust-based Service Provider Selection in Open Environments.

Bjork, B.-C., 2002. *The Impact of Electronic Document on Construction Information Management.* Swedish School of Economics and Business Administration, s.n.

Boran, F., Genc, S., Kurt, M. & Akay, D., 2009. A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Systems with Applications,* Volume 36, p. 11363–11368.

Bottani, E. & Rizzi, A., 2006. A fuzzy TOPSIS methodology to support outsourcing of logistics services. *Supply Chain Management: An International Journal,* pp. 294-308.

Büyüközkan, G., 2004. Multi-criteria decision making for e-marketplace selection. *Internet Research,* pp. 139-154.

Buyukozkan, G., Feyzioglu, O. & Nebol, E., 2008. Selection of the strategic alliance partner in logistics value chain. *International Journal of Production Economics,* pp. 148-158.

Cakravastia, A., Toha, I. & Nakamura, N., 2002. A two-stage model for the design of supply chain networks. *International Journal of Production Economics,* pp. 231-248.

Chamodrakas, I., Batis, D. & Martakos, D., 2010. Supplier selection in eletronic marketplaces using satisficing and fuzzy AHP. *Expert Systems with Applications,* pp. 490-498.

Chan, F. et al., 2008. Global supplier selection: a fuzzy AHP approach. *International Journal of Production Research,* 46(14), pp. 3825-3857.

Chang, C.-W., Wu, C.-R. & Chen, H.-C., 2008. Using expert technology to select unstable slicing machine to control wafer slicing quality via fuzzy AHP. *Expert Systems with Applications,* pp. 2210-2220.

Chang, S.-I., Yen, D., Ng, C.-P. & Chang, W.-T., 2010. An Analysis Of IT/IS outsourcing provider selection for small and medium size enterprises in Taiwan. *Information & Management.*

Chase, R. B., Jacobs, F. R. & Aquilano, N. J., 2000. *Operations Management for competitive advantage.* Chicago: Irwin Publishing Co..

Chen, K.-Y. & Wu, W.-T., 2011. Applying analytic network process in logistics service provider selection - A case study of the industry investing in southeast Asia. *International Journal of Electronic Business Mannagement,* 9(1), pp. 24-36.

Choi, T. & Hartley, J., 1996. An exploration of supplier selection practices across the supply chain. *Journal of Operations Management,* pp. 333-343.

Chou, S. & Chang, Y., 2008. A decision support system for supplier selection based on a strategy-aligned fuzzy SMART approach. *Expert Systems with Applications,* Volume 34, pp. 2241-2253.

Chowdhary, N. & Prakash, M., 2007. Prioritizing service quality dimensions. *Managing Service Quality,* pp. 493-509.

Christopher, M. & Holweg, M., 2011. "Supply Chain 2.0": managing supply chains in the era of turbulence. *International Journal of Physical Distribution & Logistics Management,* 41(1), pp. 63-82.

Christopher, M. L., 1992. *Logistics and Supply Chain Management.* London: Pitman Publishing.

Colson, G. & Dorigo, F., 2004. A public warehouses selection support system. *European Journal of Operational Research,* pp. 332-349.

Cook, R. L., 1997. Case-Based Reasoning Systems in Purchasing: Applications and Development. *International Journal of Purchasing and Materials Management,* pp. 32-40.

Cooper, M. C., Lambert, D. M. & Pagh, J. D., 1997. Supply Chain Management: More Than a New Name for Logistics. *The International Journal of Logistics Management,* 8(1), pp. 1-14.

CSCMP, C. o. S. C. M. P., s.d. *CSCMP Supply Chain Management Definitions.* [Online]
Available at: http://cscmp.org/aboutcscmp/definitions.asp
[Consultato il giorno March 2012].

Da Silva, R., Davies, G. & Naude, P., 2002. Assessing customer orientation in the context of buyer/supplier relationships using judgmental modelling. *Industrial Marketing Management,* pp. 241-252.

Dahel, N. E., 2003. Vendor selection and order quantity allocation in volume discount environments. *Supply Chain Management: An International Journal,* pp. 335-342.

Dalkey, N. C., 1969. The Delphi Method: an experimental study of group opinion. *The Rand Corporation,* pp. 1-87.

Das, A. & Buddress, L., 2007. Evaluating Prospective e-Providers: An Empirical Study. *Journal of Supply Chain Management,* pp. 31-46.

de Boer, L., Labro, E. & Morlacchi, P., 2001. A review of methods supporting supplier selection. *Journal of Purchasing and Supply Management,* pp. 75-89.

de Boer, L. & van der Wegen, L., 2003. Practice and promise of formal supplier selection: A study of four empirical cases. *Journal of Purhcasing and Supply Management,* pp. 109-118.

Degraeve, Z., Labro, E. & Roodhoofi, F., 2004. Total cost of ownership purchasing of a service: The case of airline selection at Alcatel Bell. *European Journal of Operational Research,* pp. 23-40.

Degraeve, Z., Labro, E. & Roodhooft, F., 2000. An evaluation of vendor selection models from a total cost of ownership perspective. *European Journal of Operational Research,* pp. 34-58.

Degraeve, Z. & Roodhooft, F., 1999. Effectively Selecting Suppliers Using Total Cost of Ownership. *Journal of Supply Chain Management,* pp. 5-11.

Degraeve, Z. & Roodhooft, F., 2000. A mathematical programming approach for procurement using activity based costing. *Journal of Business Finance and Accounting,* pp. 69-98.

Delbecq, A., Van de Ven, A. & Gustafson, D., 1975. *Group Techniques for Program Planning: A Guide to Nominal and Delphi Processes.* Glenview, IL: Scott, Foresman and Co..

Demirtas, E. & Ustun, O., 2008. An integrated multiobjective decision making process for supplier selection and order allocation. *Omega: The International Journal of Management Science,* Volume 36, pp. 76-90.

Dickson, G., 1966. An analysis of vendor selection systems and decisions. *Journal of Purchasing,* pp. 5-17.

Ebrahimnejad, S. et al., 2011. A novel two-phase group decision making approach for construction project selection in a fuzzy environment. *Applied Mathematical Modelling.*

Efendigil, T., Onut, S. & Kongar, E., 2008. A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness. *Computer & Industrial Engineering,* pp. 269-287.

Ellram, L., 1990. The supplier selection decision in strategic partnerships. *Journal of Purchasing and Material Management,* pp. 8-12.

Elmuti, D., 2002. The Perceived Impact of Supply Chain Management on Organizational Effectiveness. *The Journal of Supply Chain Management,* Volume 59, p. 49.

Ertugrul, I. & Karakasoglu, N., 2009. Performance evaluation of Turkish cement firms with fuzzy analytic hierarchy process and TOPSIS methods. *Expert Systems with Applications,* Volume 36, pp. 702-715.

Europe's Information Society, 2011. *European legislation on eSignature.* [Online]
Available at:
http://ec.europa.eu/information_society/policy/esignature/eu_legislation/index_en.htm
[Consultato il giorno 17 07 2012].

Faez, F. G. S. O. C., 2009. Vendor selection and order allocation using an integrated fuzzy case-based reasoning and mathematical programming model. *International Journal of Production Economics,* pp. 395-408.

Faris, C. R. P. W. Y., 1967. Industrial buying and creative marketing. In: s.l.:Allyn & Bacon (Boston).

Fawcett, S. E. & Magnam, G. M., 2002. The rhetoric and reality of supply chain integration. *International Journal of Physical Distribution & Logistics Management,* 32(5), pp. 339-361.

Fitzgerald, G., 1998. Evaluating Information Systems Projects: A multi dimensional approach. *Journal of Information Technology,* pp. 15-27.

Gauthier, C., 2005. Measuring corporate social and environmental performance: the extended life-cycle assessment. *Journal of Business Ethics,* 59(1), p. 199–206.

Gencer, C. G. D., 2007. Analytic network process in supplier selection: A case study in an electronic firm. *Applied Mathematical Modelling,* pp. 2475-2486.

Ghobadian, A. S. A. K. T., 1993. *A computerized vendor rating system.* Nottingham, UK, s.n., pp. 321-328.

Ghodsypour, S. H. & O'Brien, C., 1998. A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming. *International Journal of Production Economics,* pp. 199-212.

Ghodsypour, S. & O'Brien, C., 1998. A decision support system for supplier selection using an integrated analytical hierarchy process and opeartions research methods. *International Journal of Production Economics.*

Ghodsypour, S. O. C., 2001. The total costs of logistics in supplier selection, under conditions of multiple sourcing criteria and capacity constraint. *International Journal of Production Economics,* pp. 15-27.

Gryna, F., 2001. *Supply Chain Management: Quality planning and analysis.* New York: The McGraw-Hill Companies, Inc..

Gumus, A. T., 2009. Evaluation of hazardous waste transportation firms by using a two steps fuzzy-AHP and TOPSIS methodology. *Expert Systems with Applications,* pp. 4067-4074.

Ha, S. & Krishman, R., 2008. A hybrid approach to supplier selection for the maintenance of a competitive supply chain. *Expert Systems with Applications,* Volume 34, pp. 1303-1311.

Hertz, S. & Alfredsson, M., 2003. Strategic development of third party logistics providers. *Industrial Marketing Management,* pp. 139-149.

Hill, A. & Scudder, G., 2002. The use of electronic data interchange for supply chain coordination in the food industry. *Journal of Operations Management,* Volume 20, pp. 375-387.

Huang, S. & Keskar, H., 2007. Comprehensive and configurable metrics for supplier selection. *International Journal of Production Economics,* Volume 105, pp. 510-523.

Humphreys, P. K. W. Y. K. C. F., 2003. Integrating environmental criteria into the supplier selection process. *Journal of Materials Processing Technology,* pp. 349-356.

Jharkharia, S. S. R., 2007. Selection of logistics service provider: An analytic network process (ANP) approach. *Omega: The International Journal of Management Science,* pp. 274- 289.

Kaliontzoglou, A., Boutsi, P. & Polemi, D., 2006. eInvoke: Secure e-Invoicing based on web services. *Electronic Commerce Research,* pp. 337-353.

Karantjias, A., Papastergiou, S. & Polemi, D., 2007. *Innovative, secure and interoperable E/M-Governmental invoicing.* s.l., The 18th Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'07) .

Kilincci, O. & Onal, S., 2011. Fuzzy AHP approach for supplier selection in a washing machine company. *Expert systems with application,* Volume 38, pp. 9656-0664.

Klundert, J. K. J. S. F. W. M., 2005. Selecting telecommunication carriers to obtain volume discounts. *Interfaces,* pp. 124-132.

Koch, B., 2012. *E-Invoicing / E-Billing 2012,* Wil, Switzerland: Billentis.

Koul, S., Saraswat, A. & Verma, R., 2011. *Evaluation and Ranking of Supplier at a Service Firm Using Analytic Hierarchy Process.* World Congress of Information and Communication Technologies, s.n., pp. 922-927.

Kraljic, P., 1983. Purchasing must become supply management. *Harvard Business Review,* pp. 109-117.

La Londe, B. J. & Masters, J. M., 1994. Emerging Logistics Strategies: Blueprints for the Next Century. *Journal of Physical Distribution & Logistics Management,* 24(7), pp. 35-47.

Lambert, D. M. & Cooper, M. C., 2000. Issues in Supply Chain Management. *Industrial Marketing Management,* Volume 29, pp. 65-83.

Lambert, D. M., Stock, J. R. & Ellram, L. M., 1998. *Fundamentals of Logistics Management.* Boston: Irwin/McGraw-Hill.

Lam, K.-C., Tao, R. & Lam, M. C.-K., 2010. A material supplier selection model for property developers using Fuzzy Principal Component Analysis. *Automation in Construction,* Volume 19, pp. 608-618.

Lao, S. C. K. H. G. T. Y. C. N., 2011. Determinant of the success factors in supply chain networks: a Hong Kong-based manufacturer's perspective. *Measuring Business Excellence,* pp. 34-48.

Larson, P. & Kulchitsky, J., 2000. The Use and Impact of Communication Media in Purhcasing and Supply Management. *The Journal of Supply Chain Management,* pp. 29-40.

Lee, A. H., 2009. A fuzzy supplier selection model with the consideration of benefits, opportunities, costs and risks. *Expert Systems with Applications,* pp. 2879-2893.

Lee, H. L., 2002. Aligning Supply Chain Strategies with Product Uncertainties. *California Management Review,* 44(3).

Lee, H. L., 2004. The Triple-A Supply Chain. *Harward Business Review.*

Lee, H. L., 2004. The Triple-A Supply Chain. *Harvard Business Review,* 82(10), pp. 102-112.

Lehmann, D. R. & O'Shaughnessy, J., 1982. The Choice Criteria Used by Purchasing Managers in Buying Categories of Products. *Journal of Purchasing and Materials Management,* pp. 9-14.

Liao, Z. & Rittscher, J., 2007. A multi-objective supplire selection model under stochastic demand conditions. *International Journal of Production Economics,* Volume 105, pp. 150-159.

Li, F. et al., 2012. A 3PL supplier selection model based on fuzzy sets. *Computer & Operations research,* Volume 39, pp. 1879-1884.

Liou, J. J. & Chuang, Y.-T., 2010. Developing a hybrid multi-criteria model for supplier selection of outsourcing providers. *Expert systems with applications,* pp. 3755-3761.

Liou, J., Wang, H., Hsu, C. & Yin, S., 2011. A hybrid model for selection of an outsourcing provider. *Applied Mathematical Modelling,* Volume 35, p. 5121–5133.

Liu, H.-T. & Wang, W.-K., 2009. An integrated fuzzy approach for provider evaluation and selection in third-party logistics. *Expert systems with applications,* p. 4387–4398.

Macharis, C., J., S., De Brucker, K. & Verbeke, A., 2004. Promethee and AHP: The design of operational sinergies in multicriteria analysis. Stregthening Promethee with ideas of AHP. *European Journal of Operational Research,* pp. 307-317.

Mainardi, C. R., Salva, M. & Sanderson, M., 1999. Label of Origin: made on earth. *Strategy Management Compatition,* Volume 15, pp. 20-28.

Mandal, A. & Deshmuck, S., 1994. Vendor selection using interpretative structural modelling (ISM). *International Journal of Operations and Production Management,* pp. 52-59.

Marasco, A., 2007. Third-party logistics: A literature review. *International Journal of Production Economics.*

Martin, A., 1994. *Infopartnering: The Ultimate Strategy for Achieving Efficient Consumer Response.* s.l.:Oliver Wight Publications.

McGinnis, M., Kochunny, C. & Ackerman, K., 1995. Third pary logistics choice. *International Journal of Logistics Management,* pp. 93-102.

Mentzer, J. T. et al., 2001. Defining Supply Chain Management. *Journal of Business Logistics,* 22(2), pp. 1-27.

Mikhailov, L., 2002. Fuzzy analytical approach to partnership selection in formation of virtual enterprises. *Omega,* pp. 393-401.

Millet, I. & Wedley, W., 2002. Modelling Risk and Uncertainty with the Analytic Hierarchy Process. *Journal of Multi-criteria Decision Analysis,* pp. 97-107.

Moberg, C. & Speh, T., 2004. Third party warehousing selection: A comparison of national and regional firms. *Mid-American Journal of Business,* pp. 71-76.

Monczka, R. & Carter, J., 1988. Implementing Electronic Data Interchange. *Journal of Purchasing and Materials Management,* 24(2), pp. 2-9.

Morse, W., 1983. Measuring Quality Costs. *Cost and Management,* pp. 16-20.

Muprhy, E., 1998. Information Technology could transform logistics. *Purhcasing,* pp. 115-118.

Muralidharan, C., Anatharam, N. & Deshmukh, S., 2002. A multi-criteria group decision making model for supplier rating. *Journal of Supply Chain Management,* pp. 22-33.

Nasseri, H., 2008. Fuzzy numbers: Positive and Nonnegative. *International Mathematical Forum,* pp. 1777-1780.

Ng, W. L., 2008. An efficient and simple model for multipl criteria supplier selection problem. *European Journal of Operational Research,* Volume 186, pp. 1059-1067.

Nienhuis, J. J. & Bryant, C., 2010. *E-invoicing 2010. European market guide,* s.l.: Gilbert Lichter (EBA) and Chiel Liezenberg (Innopay).

Noci, G., 1997. Designing 'green' vendor rating systems for the assessment of a supplier's environmental performance. *European Journal of Purchasing & Supply Management,* 3(2), pp. 103-114.

Observatory on Electronic Invoicing and Dematerialization, 2008. *Electronic Invoicing as a "keystone" in the collaboration between companies, banks and PA,* Milano: Dipartimento di Ingeneria Gestionale.

Observatory on Electronic Invoicing and Dematerialization, 2009. *Joint Collaboration: a powerful driver for Electronic Invoicing in Italy,* Milano: Dipartimento di Ingegneria Gestionale.

Observatory on Electronic Invoicing and Dematerialization, 2010. *Electonic Invoicing in Italy: reporting from the field,* Milano: Dipartimento di Ingegneria Gestionale.

Okoli, C. & Pawlowski, S., 2004. The Delphi method as a research tool. an example, design considerations and applications. *Information and Management,* pp. 15-29.

Oliveira, R. C. & Lourenço, J. C., 2002. A multi-criteria model for assigning new orders to service suppliers. *European Journal of Operational Research,* pp. 390-399.

Onut, S., Kara, S. & Isik, E., 2009. Long term supplier selection using a combined fuzzy MCDM approach: A case study for a telecommunication company. *Expert Systems with Applications,* Volume 36, p. 3887–3895.

Opricovic, S. & Tzeng, G.-H., 2004. Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research,* pp. 445-455.

Opricovic, S. & Tzeng, G.-H., 2007. Extended VIKOR method in comparison with outranking methods. *European Journal of Operational Research,* pp. 514-529.

Pan, A., 1989. Allocation of order quantity among suppliers. *Journal of Purchasing and Materials Management,* pp. 36-9.

Patton, W., 1996. Use of Human Judgement Models in Industrial Buyers' Vendors Selection Decisions. *Industrial Marketing Management,* pp. 135-149.

Pearson, J. & Ellram, L., 1995. Supplier selection and evaluation in small versus large eletronics firms. *Journal of Small Business Management,* pp. 53-65.

Percin, S., 2009. Evaluation of a third-party logistics (3PL) providers by using a two-phase AHP and TOPSIS methodology. *Benchmarking: An International Journal,* 16(5), pp. 588-604.

Power, D., Bhakoo, V. & Sharafali, M., 2007. Adding value through outsourcing Contribution of 3PL services to customer performance. *Management Research News,* pp. 228-235.

Pramatari, K., 2007. Collaborative supply chain practices and evolving technological approaches. *Supply Chain Management: An International Journal,* 12(3), pp. 210-220.

Ramanathan, R., 2001. A note on the use of the analityc hierarchy process for environmental impact assessment. *Journal or Environmental Management,* pp. 27-35.

Razmi, J., Rafiei, H. & Hashemi, M., 2009. Designing a decision support system to evaluate and select suppliers using fuzzy analytic network process. *Computers & Industrial Engineering,* Volume 57, p. 1282–1290.

Saaty, T. L., 1990. How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research,* pp. 9-26.

Saaty, T. L., 2004. Fundamentals of the Analytic Network Process - Dependence and feedback in decision-making with a single network. *Journal of Systems Science and Systems Engineering,* pp. 129-157.

Saaty, T. L., 2008. Decision making with the analytic hierarchy process. *International Journal of Sciences,* pp. 83-98.

Saaty, T. L. & Vargas, L. G., 1996. *Decision Making with the Analytic Network Process.* s.l.:International Series in Operations Research & Management Science.

Sackman, H., 1975. *Delphi Critique.* Boston, MA: Lexington Books.

Salmony, M. & Harald, B., 2010. E-invoicing in Europe: now and the future. *Journals of payment strategy and systems,* 4(4), pp. 371-380.

Salmony, M. & Harald, B., 2010. E-invoicing in Europe: now and the future. *Journals of payment strategy and systems,* 4(4), pp. 371-380.

Sanayei, A., Mousavi, S. & Yazdankhah, A., 2010. Group decision making process for supplier selection with VIKOR under fuzzy environment. *Expert Systems with Applications,* pp. 24-30.

Sarkis, J. & Talluri, S., 2002. A model for strategic supplier selection. *Journal of Supply Chain Management,* p. 18.

Schaefer, C., 2010. A solution bundle. *Cash Management. Electronic invoicing,* pp. 4-9.

Sevkli, M. et al., 2007. An application of data envelopment analytic hierarchy process for supplier selection: a case study of BEKO in Turkey. *International Journal of Production Research,* 45(9), pp. 1973-2003.

Shankarnarayanan, S., 1999. Using IT to Gain a Competitive Advantage. *International Journal of Production Research,* p. 4509.

Shaw, K., Shankar, R., Yadav, S. & Thakur, L., 2012. Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain. *Expert Systems with Applications,* Volume 39, p. 8182–8192.

Sonmez & Mahmut, 2006. A Review and Critique of Supplier Selection Process and Practices. *Business School Occasional Papers Series.*

Sonmez, M. & Moorhouse, A., 2010. Purchasing professional services: which decision criteria?. *Management Decision,* 48(2), pp. 189-206.

Sparks & Wagner, 2., 2003. Retal exchanges: a research agenda. *Supply Chain Management: An International Journal,* 8(3), pp. 201-208.

Stefansson, G., 2002. Business-to-business data sharing: A source for integration of supply chains. *International Journal of Production Economics,* Volume 75, pp. 135-146.

Sun, C., Pan, Y. & Bi, R., 2010. Study on Third-Party Logistics Service Provider Selection Evaluation Indices System Based on Analytic Network Process with BOCR. *IEEE.*

Sung, W., 2001. Application of Delphi method, a qualitative and quantitative analysis, to the healthcare management. *Journal of Healthcare Management,* pp. 11-19.

Talluri, S. & Baker, R., 1996. *Quantitative framework for designing efficient business process alliances.* s.l., s.n., pp. 665-661.

Tan, P., Goh, A. & Lee, S., 2008. A Context Model for B2B Collaborations. *IEEE Computer Society,* pp. 108-116.

Teltumbde, A., 2000. A Framework for Evaluating ERP Projects. *International Journal of Production Research,* pp. 4507-4520.

TheClimateGroup, 2008. *Smart 2020: enabling the low carbon economy in the information age,* s.l.: s.n.

Ting, S. & Cho, D., 2008. An integrated approach for supplier selection and purchasing decisions. *Supply Chain Management: An international Journal,* pp. 116-127.

Tsai, C.-H., Chang, C.-L. & Chen, L., 2003. Applying Grey Relational Analysis to the Vendor evaluation model. *International Journal of The Computer, The Internet and Management,* 11(3), pp. 43-53.

Ustun, O. & Demirtas, E., 2008. Multi-period lot-sizing with supplier selection using achievement scalarizing functions. *Computers & Industrial Engineering,* Volume 54, pp. 918-931.

Vaidya, O. & Kumar, S., 2006. Analytic Hierarchy Process: An overview of applications. *European Journal of Operational Research,* pp. 1-29.

Vijayvargiya, A. & Dey, A., 2010. An analytical approach for selection of a logistics provider. *Management decision,* 48(3), pp. 403-418.

Vinodh, S., Ramiya, R. & Gautham, S., 2011. Application of fuzzy analytic network process for supplier selection in a manufacturing organisation. *Expert systems with applications,* Volume 38, pp. 272-280.

Walton, S. & Marucheck, A., 1997. The Relationship between EDI and Supplier Reliability. *International Journal of Purchasing and Materials Management,* 33(3), pp. 30-35.

Wang, D., Ip, W. & Yung, K., 2001. A heuristic genetic algorithm for subcontractor selection in a global manufacturing environment. *IEEE Transaction on Systems, Man and Cybernetics Part C: Applications and Reviews,* pp. 189-198.

Wang, T.-C. & Chen, Y.-H., 2007. Applying consistent fuzzy preference relations to partnership selection. *Omega,* pp. 383-388.

Watkinson, I., 2010. An end to the paper chase. *Cash Management. E-invoicing,* pp. 2-6.

Weber, C. C. J. B. W., 1991. Vendor selection criteria and methods. *European Journal of Operational Research,* pp. 2-18.

Weber, C., Current, J. & Desai, A., 1998. Non-cooperative negotiation strategies for vendor selection. *European Journal of Operational Research,* pp. 208-223.

Wilding, R. & Juriado, R., 2004. Customer perceptions on logistics outsourcing in the European consumer goods industry. *International Journal of Physical Distribution & Logistics Management,* pp. 628-644.

Wilson, E., 1994. The relative importance of supplier selection criteria: A review and update. *International Journal of Purchasing and Materials Management,* p. 35.

Woo, K. & Ennew, C., 2004. Business-to-business relationship quality: an IMP interaction-based conceptualization and measurement. *European Journal of Marketing,* pp. 1252-1271.

Xia, W. & Wu, Z., 2007. Supplier selection with multiple criteria in volume discount environments. *Omega,* Volume 35, pp. 494-504.

Xu, J., 2002. New pattern of supply chain management – the fourth distribution channel. *Policy-making reference,* 15(1), pp. 11-15.

Yang, C. & Chen, B., 2006. Supplier selection using combined analytical hierarchy process and grey relational analysis. *Journal of Manufacturing Technology Management,* pp. 926-941.

Yeh, W.-C. & Chuang, M.-C., 2011. Using multi-objective genetic algorithm for partner selection in green supply chain problems. *Expert Systems with Applications,* Volume 38, pp. 4244-4253.

Zahir, S., 1999. Clusters in group: Decision making in the vector space formulation of the analytic hierarchy process. *European Journal of Operational Research,* pp. 620-634.

Zeydan, M., Colpan, C. & Cobanoglu, C., 2011. A combined methodology for supplier selection and performance evaluation. *Expert Systems with Applications,* Volume 38, pp. 2741-2751.

Zhang, R. & Chen, R., 2009. The Dempster-Shafer Synthesis Rule for Service Supplier Selection. *IEEE,* pp. 1625-1632.

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Matto è chi spera che nostra ragione
possa trascorrer la infinita via
che tiene una sustanza in tre persone.
State contenti, umana gente, al quia;
ché se potuto aveste veder tutto,
mestier non era parturir Maria.

[Purgatorio, Canto III, v.34-39]