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BAHÇEŞEHİR UNIVERSITY

LOGISTICS OUTSOURCING AND SELECTION OF THIRD PARTY LOGISTICS SERVICE PROVIDER (3PL) VIA FUZZY AHP

Master Thesis

ERDAL ÇAKIR

İSTANBUL, 2009

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INDUSTRIAL ENGINEERING

Name of the thesis: Logistics outsourcing and Selection of third party logistics service provider (3PL) via fuzzy AHP.
Name/Last Name of the Student: Erdal ÇAKIR
Date of Thesis Defense: June 9, 2009

The thesis has been approved by the Institute of Science.

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ACKNOWLEDGMENTS

I would like to thank Assistant Professor Özalp Vayvay, my thesis supervisor, for his guidance, help, comments and revisions in improving this thesis. Without his instruction and guidance, this thesis could not be accomplished. I would also thank Prof. Dr. Cengiz Kahraman and Asst. Prof. Dr. Tunç Bozbura for their valuable comments.

I would like to express my sincere gratitude towards questionnaire repliers for their valuable responses and helpful comments, which helped much to improve the quality of the paper.

Thanks also go to TUBİTAK which supported me financially to complete my thesis.

Lastly, to Sibel: Thank you for your patience, support and love…

İSTANBUL, 2009 Erdal ÇAKIR

ABSTRACT

LOGISTICS OUTSOURCING and SELECTION of THIRD PARTY LOGISTICS SERVICE PROVIDER (3PL) VIA FUZZY AHP

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Industrial Engineering

Supervisor: Asst. Prof. Dr. Özalp Vayvay

June, 2009, 118 pages

In today's competitive business world, it is extremely important for decision makers to have access to decision support tools in order to make quick, right and accurate decisions. One of these decision making areas is logistics service provider selection. Logistics service provider selection is a multi – criteria decision making process that deals with the optimization of conflicting objectives such as quality, cost, and delivery time. If it is not supported by a system, this would be a complex and time consuming process.

In spite of the fact that the term "logistics service provider selection" is commonly used in the literature, and many methods and models have been designed to help decision makers, few efforts have been dedicated to develop a system based on any of these methods.

In this thesis, logistics service provider selection decision support system based on the analytic hierarchy process (AHP) method which has been commonly used for multi – criteria decision making problems is proposed. Inasmuch as it is believed that fuzzy concepts and usage of empirical data extend the capability of any modeling approach, integrating them into model will lead to a more powerful system. To validate choice of the Fuzzy AHP model and also to validate the conceptual design of logistics service provider selection decision support system, it is conducted a case study in an example company.

Keywords: logistics service provider selection, fuzzy AHP, 3PL

ÖZET

LOJİSTİK DIŞ KAYNAK KULLANIMI ve ÜÇÜNCÜ PARTİ LOJİSTİK ŞİRKETİNİN (3PL) BULANIK AHP YAKLAŞIMIYLA SEÇİLMESİ

Çakır, Erdal

Endüstri Mühendisliği

Tez Danışmanı: Yrd. Doç. Dr. Özalp Vayvay

Haziran, 2009, 118 sayfa

Günümüz rekabetçi iş dünyasında, hızlı, doğru ve kesin kararlar verebilmek için karar destek araçlarına sahip olabilmek karar vericiler açısından oldukça önemlidir. Karar vericilerin karar vermekte zorlandığı alanlardan biri de lojistik dış kaynak kullanımında üçüncü parti lojistik şirketinin seçilmesidir. Üçüncü parti lojistik şirketinin seçimi karar vermede düşünülen ölçütler (kalite, maliyet, dağıtım zamanı) ele alındığında, zor ve zaman alıcı bir süreçtir. Aynı zamanda bu ölçütlerin birbirleriyle çelişen amaçlarının optimize edilmesi ve ortak amaca hizmet etme düzeyleri belirlenmesi ile karar verme süreci oluşturulmalıdır. Bu etkenler ve zorluklar düşünüldüğünde bu sürecin bir sistem tarafından desteklenmeden yönetilemeyeceği aşikârdır.

"Tedarikçi seçimi" literatürde çokça kullanılmasına ve karar vericilere yardım etmek için birçok model ve metot geliştirilmesine rağmen, bu metotları kullanarak sistemsel bir yaklaşım getiren çalışma çok az bulunmaktadır.

Bu tez ile birlikte, üçüncü parti lojistik şirketinin seçimi için analitik hiyerarşi sürecine (AHP) dayalı karar destek sistemi önerilecektir. Karar vermede etkili olacak kriterlerin aralarındaki ilişkilerin kesin ifadelerle belirtilemeyeceği düşünüldüğünde karar destek aşamasına bulanık mantık yaklaşımının dâhil edilmesi modelin daha güçlü olmasını doğuracak, sonuç olarak daha akılcı ve doğru çözümler üretmesine yardımcı olacaktır. Bulanık analitik hiyerarşi süreci ile kurulacak olan modeli test etmek için örnek bir şirkette uygulama yapılacaktır.

Anahtar kelimeler: Üçüncü parti lojistik şirket seçimi, Bulanık AHP, 3PL

TABLE OF CONTENTS

LIST OF TABLES vii

LIST OF FIGURES ix

ABBREVIATIONS x

1. INTRODUCTION 1

1.1 MOTIVATION OF THE RESEARCH 1
1.2 RESEARCH OBJECTIVES 3
1.3 THESIS ORGANIZATION 3

2. LITERATURE REVIEW 5

2.1 LOGISTICS 5
2.1.1 Phases of logistics 5
2.1.1.1 Logistics as a functional specialization 7
2.1.1.2 Logistics as a coordinative function 8
2.1.1.3 Logistics as enabler of process orientation within the firm 9
2.1.1.4 Logistics as a supply chain management 10
2.1.2 Performance effects of logistics development 12
2.2 OUTSOURCING 14
2.2.1 What is outsourcing 14
2.2.2 Why organizations outsource 16
2.2.3 Critical success factors of outsourcing 20
2.3 LOGISTICS OUTSOURCING 22
2.3.1 Origin and definition 22
2.3.2 Benefits and risks of logistics outsourcing 24
2.3.2.1 Advantages of logistics outsourcing 24
2.3.2.2 Disadvantages of logistics outsourcing 26
2.3.3 Balance Sheet Impact of Logistics Outsourcing 27
2.3.4 The role of logistics service providers in logistics outsourcing 29
2.3.5 General logistics outsourcing perspective in Turkish firms 31
2.3.6 Logistics outsourcing researches 32
2.4 SELECTION OF LOGISTICS OUTSOURCING COMPANY (3PL) 39
2.4.1 Selection Methods 41
2.4.2 Specific problems related to the selection of a provider 44
2.4.3 Criteria for the selection of a provider 45

3. DATA AND METHODOLOGY 50

3.1 METHODOLOGY 50
3.1.1 Analytical Hierarchy Process 50
3.1.2 Fuzzy Set Theory 52
3.1.3 Fuzzy Numbers 52
3.1.4 Algebraic Operations on TFNs 54
3.1.5 Fuzzy Analytical Hierarchy Process (FAHP) 54
3.1.6 Algorithm of FAHP Method 55
3.1.7 Applications of Fuzzy AHP methodology in literature 58
3.2 APPLICATION OF FAHP METHODOLOGY 61
3.2.1 A Case Company 61
3.2.2 Structuring Selection Model 61
3.2.3 Potential Providers 64

3.2.4 Pair wise comparisons matrices 65
3.2.4.1 Questionnaire Design and Data Collection 65
3.2.4.2 Integration the Opinions of Decision Makers 66
3.2.5 Data Input and Analysis using Fuzzy AHP 67
3.2.5.1 The Fuzzy Evaluation Matrix with Respect to Goal 67
3.2.5.2 Evaluation of the sub-attributes with respect to "Cost of Service" 72
3.2.5.3 Evaluation of the sub-attributes with respect to "Financial Performance" 72
3.2.5.4 Evaluation of the sub-attributes with respect to "Operational Performance" 73
3.2.5.5 Evaluation of the sub-attributes with respect to "Reputation of the 3PL" 74
3.2.5.6 Evaluation of the sub-attributes with respect to "Long-term Relationships" 74
3.2.5.7 Pair wise comparison of alternatives 75

4. RESULTS 82

5. DISCUSSION 85

6. CONCLUSION 88

REFERENCES 92

APPENDICES 106

APPENDİX A.1 KEY LOGİSTİCS OUTSOURCİNG RELATED FİNDİNGS SİNCE 1999 TO PRESENT 107

APPENDİX A.2 QUESTİONNAİRE FORMS USED TO FACİLİTATE COMPARİSONS OF MAİN AND SUB-ATTRİBUTES 112

LIST OF TABLES

Table 2.1: Reasons for outsourcing – summary of surveys 18
Table 2.2: Balance Sheet Impact of Logistics Outsourcing 28
Table 2.3: Summary of literature on the criteria for the selection of a provider 46
Table 3.1: The fundamental scale 51
Table 3.2: Triangular fuzzy numbers 53
Table 3.3: Qualifications of potential providers 64
Table 3.4: Pair – wise comparison matrix for main attributes 68
Table 3.5: Summary of priority weights of main criteria with respect to goal 69
Table 3.6: Pair – wise comparison matrix for the sub-attributes of "Cost of Service" 72
Table 3.7: Summary of priority weights for the sub attributes of the "Cost of Service" 72
Table 3.8: Pair – wise comparison matrix for the sub-attributes of "Financial Performance" 72
Table 3.9: Summary of priority weights for the sub attributes of the "Financial Performance" 73
Table 3.10: Pair – wise comparison matrix for the sub-attributes of "Operational Performance" 73
Table 3.11: Summary of priority weights for the sub attributes of the "Operational Performance" 73
Table 3.12: Pair – wise comparison matrix for the sub-attributes of "Reputation of the 3PL" 74
Table 3.13: Summary of priority weights for the sub attributes of the "Reputation of the 3PL" 74
Table 3.14: Pair – wise comparison matrix for the sub-attributes of "Long-term Relationships" 74
Table 3.15: Summary of priority weights for the sub attributes of the "Long-Term Relationships" 75
Table 3.16: Reading table of qualifications of potential providers 75
Table 3.17: An Example matrix of reading table 76
Table 3.18: Pair-wise comparison for the alternatives regarding to sub-attributes of "cost of service" 77
Table 3.19: Summary of priority weights for the alternatives regarding to "cost of service" 77
Table 3.20: Pair-wise comparison for the alternatives regarding to sub-attributes of "financial performance" 78
Table 3.21: Summary of priority weights for the alternatives regarding to "financial performance" 78
Table 3.22: Pair-wise comparison for the alternatives regarding to sub-attributes of "operational performance" 78
Table 3.23: Summary of priority weights for the alternatives regarding to "operational performance" 79
Table 3.24: Pair-wise comparison for the alternatives regarding to sub-attributes of "reputation of the 3PL" 79
Table 3.25: Summary of priority weights for the alternatives regarding to "reputation of the 3PL" 80

Table 3.26: Pair-wise comparison for the alternatives regarding to sub-attributes of "long-term relationships"..... 80
Table 3.27: Summary of priority weights for the alternatives regarding to "long-term relationships"..... 81
Table 4.1: Priority weights of main and sub-attributes, and alternatives 83

LIST OF FIGURES

Figure 2.1 : The four phases of logistics development 6
Figure 2.2 : Performance effects of logistics 13
Figure 3.1: A triangular fuzzy number, $\tilde{M}$ 53
Figure 3.2: The intersection between M_1 and M_2 57
Figure 3.3: Decision Hierarchy 63
Figure 3.4: Geometric average example in Microsoft Excel 67
Figure 3.5: Fuzzy AHP Program Screen I 70
Figure 3.6: Fuzzy AHP Program Screen II 71

ABBREVIATIONS

Logistics Service Provider	:	LSP
Third Party Logistics Service Provider	:	3PL

1. INTRODUCTION

1.1 Motivation of the Research

Determining the most suitable logistics service provider is an important problem to deal with when managing supply chain of a company. It is vital in enhancing the competitiveness of the company and has a positive impact on expanding the life span of the company. The logistics service provider selection is a multi-criteria problem which includes both quantitative and qualitative criteria some of which can conflict each other (Güner 2005).

One of the most important functions of the logistics department is the selection of efficient logistics service providers, because it brings significant savings for the organization. While choosing the best provider, a logistics manager might be uncertain whether the selection will satisfy completely the demands of their organizations (Bevilacqua & Petroni 2002). Experts agree that no best way exists to evaluate and select providers, and thus organizations use a variety of approaches. The overall objective of the provider evaluation process is to reduce risk and maximize overall value to the purchaser (Bello 2003).

There are several supplier selection applications available in the literature. Verma and Pulman (1998) examined the difference between managers' ratings of the perceived importance of different supplier attributes and their actual choice of suppliers in an experimental setting. They used two methods: a Likert scale set of questions and a discrete choice analysis (DCA) experiment. Ghodsypour *et al.* (1998) proposed an integration of an analytical hierarchy process and linear programming to consider both tangible and intangible factors in choosing the best suppliers and placing the optimum order quantities among them such that the total value of purchasing becomes maximum.

Wong *et al.* (2001) introduced an approach of combined scoring method with fuzzy expert systems to perform the supplier assessment. Bevilacqua and Petroni (2002) developed a system for supplier selection using fuzzy logic. Kahraman *et al.* (2003)

used fuzzy AHP to select the best supplier firm providing the most satisfaction for a white good manufacturer established in Turkey. Dulmin and Mininno (2003) proposed a multi-criteria decision aid method (promethee/gaia) to supplier selection problem. They applied the model to a mid-sized Italian firm operating in the field of public road and rail transportation. Chan and Chan (2004) reported a case study to illustrate an innovative model which adopts AHP and quality management system principles in the development of the supplier selection model. Xia and Wu (2005) proposed an integrated approach of AHP improved by rough sets theory and multi-objective mixed integer programming to simultaneously determine the number of suppliers to employ and the order quantity allocated to these suppliers in the case of multiple sourcing, multiple products, with multiple criteria and with supplier's capacity constraints.

It is almost impossible to find a provider that excels in all areas. In addition, some of the criteria are quantitative while others are qualitative, which is certainly a weakness of existing reported approaches. Thus a methodology that can capture both the subjective and the objective evaluation measures is needed. Recently, the AHP approach was suggested for logistics service provider selection problems (Chan & Chan 2004).

The Analytical Hierarchy Process has found widespread application in decision-making problems, involving multiple criteria in systems of many levels. In the AHP, the factors that affect the system are designed in hierarchy. Then, to evaluate the decision alternatives pair-wise comparisons of elements in all levels, are done. The scores of alternatives are calculated according to obtained characteristics. The strength of the AHP lies in its ability to structure a complex, multi-person and multi-attribute problem hierarchically, and then to investigate each level of the hierarchy separately, combining the results. And also AHP is useful, practical and systematic method for provider selection. But in the traditional formulation of the AHP, human's judgments are represented with crisp numbers. However, in many practical cases the human preference model is uncertain and decision-makers might be reluctant or unable to assign exact numerical values to the comparison judgments. For instance, when evaluating different suppliers, the decision-makers are usually unsure about their level of preference due to incomplete and uncertain information about possible suppliers and their performances. Since some of the provider evaluation criteria are subjective and qualitative, it is very

difficult for the decision-maker to express the strength of his preferences and to provide exact pair-wise comparison judgments (Mikhailov & Tsvetinov 2004). For this reason, a methodology based on fuzzy AHP can help us to reach an effective decision. By this way we can deal with the uncertainty and vagueness in the decision process.

1.2 Research objectives

The objectives of this research are as follows:

i. Gain an understanding of logistics, outsourcing, logistics outsourcing and logistics service provider selection process.

ii. Find out and define the most important measures and criteria of the supplier selection process. Performing an extensive review of the literature will give an opportunity to define commonly used measures and criteria.

iii. Additionally, review supplier selection models in the literature that have been used to evaluate, rank and select suppliers and perform a detailed review of traditional AHP and fuzzy AHP models.

iv. Design, implement and deploy a decision support system for logistics service provider selection based on a fuzzy AHP model.

v. Validate the model and the system with a case study; discuss the advantages and disadvantages.

vi. Perform an assessment of decision criteria on the logistics service provider selection process

1.3 Thesis Organization

In this study, the fuzzy AHP approach is adopted to develop a provider selection model that can fulfill the requirements of the company.

This thesis is organized as follows:

In section II, a detailed discussion of logistics outsourcing and trends is provided. A summary of recent research papers related to logistics outsourcing and selection methods used in supplier selection is presented.

AHP and Fuzzy AHP models are introduced in section III. Firstly, fuzzy sets and fuzzy numbers are introduced as our comparison method is fuzzy AHP, includes fuzzy numbers and their algebraic operations. And in this section, the literature review of fuzzy AHP is given. Then, application of fuzzy AHP methodology is demonstrated in section III. Case company, selection model, potential providers, data input and analysis is explained in this section. In other words, the selection model is validated with a case study.

Results and discussions are provided in section IV and V, respectively.

The thesis ends with a summary and conclusion given in section VI.

2. LITERATURE REVIEW

2.1 Logistics

The concept of logistics in its modern form dates back to the second half to the 20th century. Since then, it has developed into a widely recognized discipline of significant importance to both theory and practice. This development is not yet completed, however, and the debate on the true meaning of logistics and its exact specifications is still ongoing:

Especially in the logistics industry it becomes apparent that neither a standardized logistics concept nor a consistent notion of logistics exists. While some reduce their understanding to simple transporting-, handling-, and warehousing operations, others view logistics more broadly as a management function.

Logistics literature supports this finding of notional heterogeneity with a multitude of different logistics definitions. Especially recognized is the 2005 definition by the Council of Supply Chain Management Professionals (CSCMP 2005, p. 63), where logistics management is seen as part of supply chain management (SCM). It is the part "*… that plans implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements.*" This definition directly refers to the importance of economical considerations (efficiency, effectiveness) and at the same time underscores the functional character of logistics.

2.1.1 Phases of logistics

Most of the concepts indicate that the development of logistics follows three or four distinct phases (Weber 2002; Bowersox & Daugherty 1987), where sometimes the most advanced two phases are viewed as a single phase only. These phases, as indicated in Figure 2.1 (Weber 2002, p. 5), are determined by the level of logistics knowledge present in a firm and require path dependent development from the lowest to the highest level of logistics knowledge.

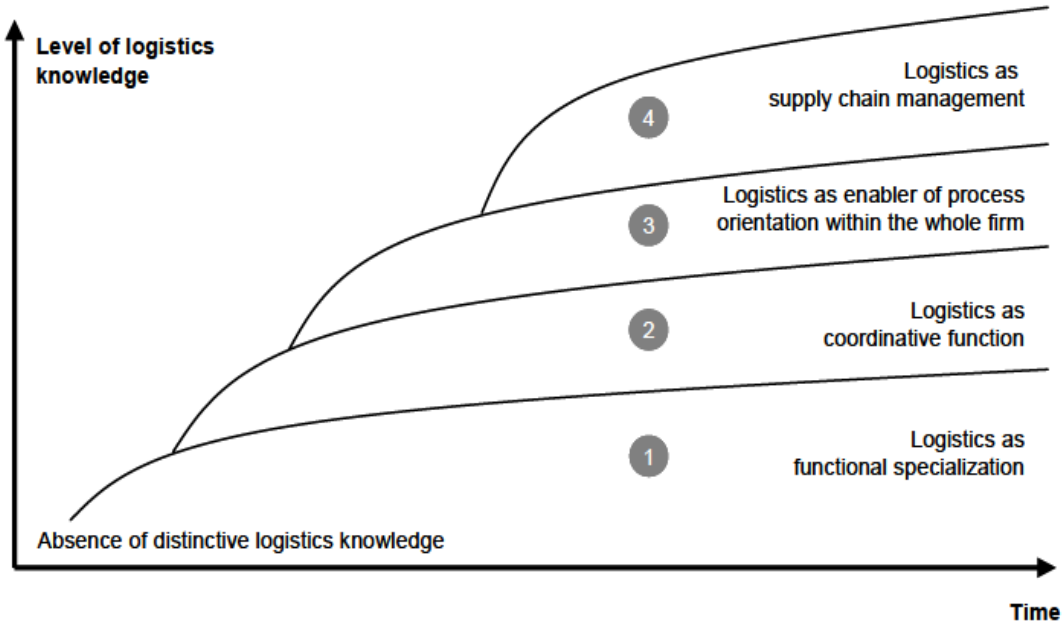

Figure 2.1 : The four phases of logistics development
Source: Weber 2002.

During the first two phases, efficiency gains of the logistical processes are emphasized, both through specialization and the cross-functional coordination of material flows. After the transition to the third and fourth phases the scope of logistics changes distinctly. It becomes a management function, whose objective is the implementation of a flow- and process orientation throughout the firm, thereby fostering logistical thinking and acting beyond the sole logistics department. However, Weber (2002, pp.3-4) points out that even when a firm has reached those higher phases of logistical development, it is important that the functions typical for the lower phases are not neglected. The different phases of logistical development reflect an underlying shift of importance. Coming from an emphasis on classical logistical activities such as transportation, handling and warehousing, the flow of information in logistics processes is of increasing concern. While in the early years of logistical development the physical capabilities of a logistics system determined its potential, this has changed until today, where the capabilities of the complementary processes of information exchange are of at least equal importance.

In the following chapters, the different phases of logistical development will be shown in greater detail.

2.1.1.1 Logistics as a functional specialization

During the first phase of its development, logistics becomes a specialized function, supplying services and processes required for the efficient flow of materials and goods. These processes mainly include the transportation, handling and warehousing of goods which previously had not been adequately addressed.

Historically, the emergence of the first phase of logistical development was caused by a severe change in the market environment in the 1950's. The traditional suppliers' markets turned into buyers' markets, requiring new and more sophisticated flows of materials and goods. In contrast to other functions, such as procurement or production, the logistics function back then was underdeveloped and logistics responsibilities were scattered throughout the organization. For this reason, a concentration on the optimization of this function promised broad room for improvement.

Through the functional specialization, two separate benefits can be obtained, coming either from the direct optimization of individual processes or from the joint treatment of different processes. Wallenburg (2004, p.40) indicates that improvements on the process level can result from experience curve effects or economies of scale. Furthermore efficiency gains can be realized on the planning level through the application of mathematical methods, solving e.g. non-trivial transportation and warehousing problems. Beyond these improvements, optimizing different logistics processes jointly promises great potential that can only be realized if existing interdependencies are taken into account, e.g. when rising costs incurred through higher transportation frequencies are offset by savings through lower inventory levels.

On the organizational level, a specialization of the logistics function often leads to the introduction of new departments, combining transporting-, handling- and warehousing functions. At the same time, a functional division can often be observed on a firm-wide basis, created through separate efforts in the areas of procurement-, production-, and distribution-logistics. As a specialized service function, logistics is characterized by the existence of a considerable know-how spread among a clearly definable group of employees.

In summary it can be ascertained that the mastering and understanding of the requirements of the first phase of logistical development promises considerable improvements and efficiency gains and simultaneously is the necessary basis for the following phases.

2.1.1.2 Logistics as a coordinative function

After exhausting rationalization potentials during the first phase especially in distribution and transport-intense procurement functions, the focus during the second phase of logistical development is on the coordination of different functions. The efforts concentrate both on the coordination of the flow of materials and goods from source to sink and on expanding the focus towards the entire supply chain, cutting across the boundaries of the firm and comprising customers as well as suppliers.

Starting point for understanding logistics as a coordinative function was the insufficient consideration of existing interdependencies between different functions of the firm. Facilitated by existing structures, especially procurement, production, and distribution functions were optimized independently. The organizational separation of these functions, however, historically encouraged the development and cultivation of individual interests, obstructing an overall optimization of all processes. But exactly the latter was needed, since the optimization potentials due to specialization for the single functions were already exhausted. Therefore, during the second phase of logistical development, improvements can be achieved by concentrating on the coordination of the different functions. Examples given by Weber (2002, p. 11) are the coordination of lot sizes or just-in-time supply and production, where the required resources are provided exactly when needed. Resulting from the integrated understanding and planning of the procurement and production functions, cost and performance benefits emerge.

The focus thus is on influencing the extent and the structure of the demand for logistical services through appropriate coordination. In doing so, logistics is giving up the former functional separation and rather focuses on integrated processes.

This fundamental change in the understanding of logistics causes an increased heterogeneity of the function on the one hand and on the other requires an increased

interaction with the responsible management of other functions. The perceived importance of logistics increases during the second phase of logistical development as it is now seen as a means to achieve competitive advantages. The primary concern during this phase is to enable cost leadership –differentiation through performance will be targeted mainly during the following phases. The second phase is building on the know-how of the functional specialization, supplemented by substantial inter-organizational and management knowledge needed for the coordination. Therefore, not only the amplitude of the necessary logistical knowledge increases, but also its depth.

2.1.1.3 Logistics as enabler of process orientation within the firm

The transition towards the third phase of logistical development is characterized by yet another change in the relevance attached to it. Logistics now becomes a management function aiming at implementing the concept of flow orientation inside the entire firm. Historically, this development was caused by the changing economic environment. The increasing competitive pressure called for differentiation while simultaneously reducing costs. For doing so, the purely functionally designed structures and systems proved irrelevant. Yet, by adopting a stronger process orientation when supplying logistical services, complexity reductions could be achieved, thereby better addressing the shifted needs of the markets.

Because of the transition into a management function, the implementation of flow orientation is not restricted to individual corporate functions. In contrast to the approach of the second phase based on coordination, all logistical structures are generally perceived as being changeable. Thus, when implementing the concept of flow orientation, the original logistical processes transporting, handling, and warehousing lose their exposed significance. Their remaining importance comes from their contribution to the proper functioning of the flow orientation of the firm.

With the increasing importance of logistics as a management function, the required logistical knowledge increases as well. At the same time, the broad logistical know-how obtained in the first phases allows a reduction of the distinct specializations on the different logistics functions. Logistical services can now for instance be provided by the same employees responsible for supplying production- or maintenance-activities.

In practice, corporate logistics following this understanding are sometimes criticized since they may fail in some of their very basic aspects (Weber 2002, p. 19): one danger is that with the broader orientation the unique and original logistical skills may suffer. On the other hand, when logistics become a management function it runs the risk of not being adequately anchored in the organization. Consequently, the functional specialization must not necessarily be abandoned when a firm progresses towards the third phase of logistical development. Rather, it is vital to find a compromise which enables and fosters the coexistence of a functional specialization for the supply of logistical services and at the same time anchors the understanding that flow orientation as an important task of the management.

2.1.1.4 Logistics as a supply chain management

During the fourth and last phase of logistical development, logistics remains a management function, but extends its scope beyond the boundaries of the firm. Consequently, the concept of process or flow orientation is extended across the supply chain, encompassing now also suppliers and customers, thus ideally spanning from source to sink. Logistics during this phase, now being called supply chain management (SCM), aim at integrating the entire supply chain.

This understanding of the concept of supply chain management as a phase of logistical development is not undisputed. As Larson and Halldorsson (2004, pp. 1-7) point out, in the logistics science community basically four different views of SCM have developed over the years. These include the "*traditionalist*" view which understands SCM as part of logistics and the "*unionist*" view which considers logistics as part of SCM. Furthermore, the "*re-labeling*" perspective believes that what is now SCM was previously logistics. The fourth and "*intersectionist*" view finally suggests that logistics is not the union of logistics, marketing, operations, purchasing etc. but rather includes strategic and integrative elements from all these disciplines. Further insights into the diversity of understandings are given by Bechtel and Jayaram (1997) who provides an extensive retrospective review of the literature and research on supply chain management.

In the light of this multitude of different understandings it is important to establish that in this work, supply chain management is understood as the most advanced phase of logistical development.

Starting point for the development towards supply chain management was the further increasing demand of firms for more efficiency and effectiveness. Since most of the internal optimization potentials had already been exhausted, only those remained that resulted from the inefficient collaboration between firms being part of the same supply chain. The fact that during this process the individual boundaries of the firm lost part of their former dominant importance was fundamentally enabled by the tremendous progress the information and communication technologies made.

Even though supply chains are part of every economy based on the division of labor and therefore have already existed during the other phases of logistical development, it is only during the fourth phase that they obtain a widely recognized importance. Thus, what is new to this phase is the concentration on the supply chain and the introduction of inter-organizational concepts aiming at the realization of optimizing potentials by targeting gains in efficiency and effectiveness.

Due to the high complexity of the task and the divergent objective functions the realization of an inter-organizational supply chain management is accompanied by management problems. While in partnerships with low intensity the focus is usually only on the adequate supply with information, an increasing intensity requires adjustments in structures and processes as well in order to prepare the former internal structures for the now interorganizational challenges.

The management tasks during this phase of logistical development are considerable and complex. Together with the understanding of the need for inter-organizational cooperation for supplying goods and services, they are the reason why supply chain management is an own phase of the logistical development. Prerequisite for the implementation of an interorganizational flow orientation not only is the answering to the technological demands, but also the sufficient willingness and capabilities of the participating firms.

2.1.2 Performance effects of logistics development

As described above, significant advancements in the field of corporate logistics can be observed in recent years. It remains an open question, however, whether or not it is desirable for every individual firm to aim at reaching as high a level of logistics development as possible and to implement logistics as a management function, thereby enabling an interorganizational flow orientation. This will only be the case if it proves that flow orientation is a key performance driver both for logistics and firm performance.

Dehler (2001, pp. 220-226) shows empirically that the higher the flow orientation of a firm, the higher is its logistics performance due to reduced logistics costs and increased levels of logistics service.

This finding is of particular relevance, because Dehler (2001, pp. 233-244) also finds that logistics performance directly influences the overall firm performance. As indicated in Figure 2.2, lower logistics costs have a positive direct, and therefore also total, effect on financial performance. However, increased levels of logistics services have a significantly stronger total effect since they affect both the adaptiveness and the market performance of the firm, which in turn both considerably influence the financial performance.

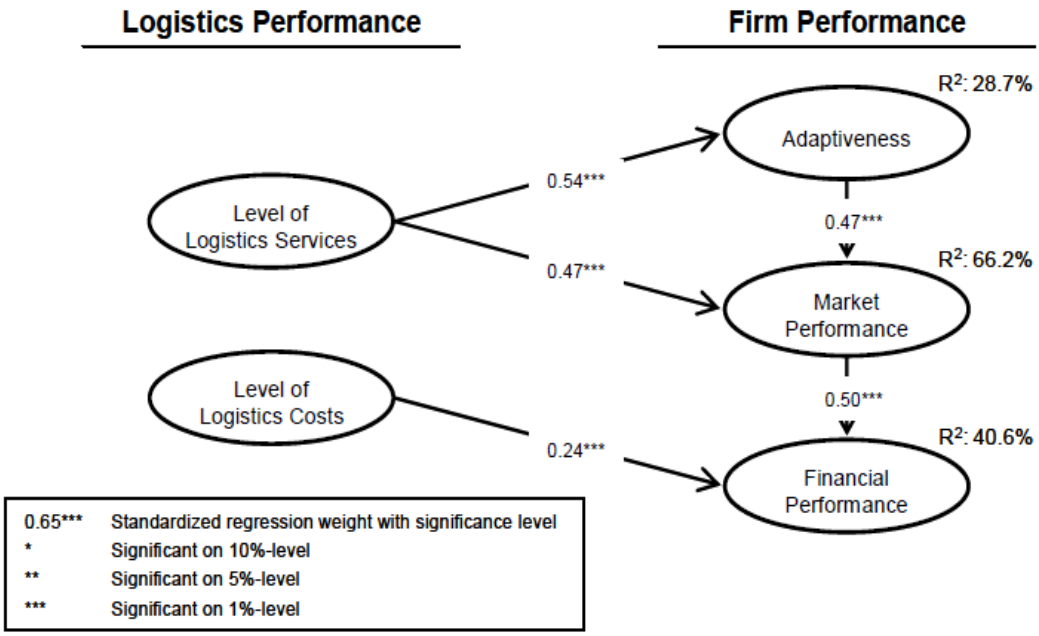

Figure 2.2 : Performance effects of logistics
Source: Dehler, 2001, pp. 233 – 244.

The findings presented above provide insights into the answer to the question whether it is desirable for every individual firm to aim at reaching as high a level of logistics development as possible: even though it may be possible that in individual cases it is not efficient to allocate extensive management capacities to creating flow orientation throughout the firm, flow orientation has in general be shown to positively influence logistics performance. Together with the finding that logistics performance is a significant driver of firm performance, the importance of flow orientation as a facilitator of logistics performance is underscored. Consequently, in general firms should aim at reaching as high a level of logistics performance as possible. This points the specific strategic direction for corporate logistics: away from functional oriented optimizations of isolated processes towards a concentration on the entire supply chain and its corresponding flows of material and information.

2.2 Outsourcing

2.2.1 What is outsourcing

Outsourcing has become a megatrend in many industries, most particularly in logistics and supply chain management (Feeney *et al.* 2005). The overall scope of outsourcing is continuing to grow, as companies focus on their core competencies and shed tasks perceived as noncore (Lindner 2004). For example, recent data indicate that the outsourcing of human resources (HR) functions is pervasive, with 94 percent of firms outsourcing at least one major HR activity, and the majority of firms planning for outsourcing expansion (Gurchiek 2005). Research assessing the outsourcing of sales, marketing and administrative functions provides parallel results, with at least portions of these functions now being outsourced in 15–50 percent of sampled firms (The Outsourcing Institute 2005; GMA 2006). Similarly, the third- and fourth-party logistics industries are booming, with between 65 percent and 80 percent of U.S. manufacturing firms contracting with or considering use of a logistics service provider in the last year (Langley *et al.* 2006). Thus, managers are increasingly feeling pressure to make the right sourcing decision, as the business consequences can be significant (McGovern & Quelch 2005). Good outsourcing decisions can result in lowered costs and competitive advantage, whereas poorly made outsourcing decisions can lead to a variety of problems, such as increased costs, disrupted service and even business failure (Cross 1995). Poor outsourcing practices can also lead to an unintended loss of operational-level knowledge.

Consider the case of Toyota Motor Corp., which by outsourcing the design and manufacture of electrical systems for its automobiles, surrendered its own capability to understand the processes required for this highly specialized work. As a result, Toyota is no longer able to leverage its own technological advantage with respect to these systems during product development (Lindner 2004). Problems such as these and others related to the outsourcing of goods and services are prevalent when outsourcing arrangements are not well understood by managers in the contracting firms.

In the 1990s, outsourcing was the focus of many industrial manufacturers; firms considered outsourcing everything from the procurement function to production and

manufacturing. Executives were focused on stock value, and huge pressure was placed on the organization to increase profits. Of course, one easy way to increase profit is by reducing costs through outsourcing. Indeed, in the mid1990s there was a significant increase in purchasing volume as a percentage of the firm's total sales. More recently, between 1998 and 2000, outsourcing in the electronics industry has increased from 15 percent of all components to 40 percent.

Consider, for instance, the athletic shoe industry, a fashion industry with products that require significant investment in technology. No company in this industry has been as successful as Nike, a company that outsources almost all its manufacturing activities. Nike, the largest supplier of athletic shoes in the world, focuses mainly on research and development on the one hand and marketing, sales, and distribution on the other. Indeed, this strategy allowed Nike to grow in the 1990s at an annual rate of about 20 percent.

Cisco's success story is even more striking. According to Peter Solvik, CIO of Cisco, Cisco's Internet-based business model was instrumental in its ability to quadruple in size from 1994 to 1998 ($1.3 billion to over $8 billion), hire approximately 1000 new employees per quarter while increasing their productivity, and save $560 million annually in business expenses. Specializing in enterprise network solutions, Cisco used, according to John Chambers, Cisco CEO, a global virtual manufacturing strategy. As he explained, "First, we have established manufacturing plants all over the world. We have also developed close arrangements with major suppliers. So when we work together with our suppliers, and if we do our job right, the customer cannot tell the difference between my own plants and my suppliers in Taiwan and elsewhere". This approach was enabled by Cisco's single enterprise system, which provides the backbone for all activities in the company and connects not only customers and employees but also chip manufacturers, component distributors, contract manufacturers, logistics companies, and systems integrators. These participants can perform like one company because they all rely on the same Web based data sources. All its suppliers see the same demand and do not rely on their own forecasts based on information flowing from multiple points in the supply chain. Cisco also built a dynamic replenishment system to help reduce supplier inventory. Cisco's average inventory turns in 1999 were 10 compared with an

average of 4 for competitors. Inventory turns for commodity items are even more impressive; they reach 25 to 35 turns a year.

Apple Computers also outsources most of its manufacturing activities; in fact, the company outsources 70 percent of its components. Apple focused its internal resources on its own disk operating system and the supporting macro software to give Apple products their unique look and feel.

Making the right outsourcing decision requires a clear understanding of the broad array of potential engagement options, risks and benefits, and the appropriateness of each potential arrangement for meeting business objectives. Many variations of outsourcing alternatives exist, resulting in a lexicon of terms, such as out-tasking, collocation, managed services and business process outsourcing. This has led to confusion for many managers, who feel pressure to make the right decisions and often view outsourcing as an all or nothing proposition to offload and bring down the costs of noncore activities. In fact, one of the biggest misconceptions about outsourcing is that it is a fixed event or a simple make-or-buy decision. In reality, outsourcing is an umbrella term that encompasses a spectrum of arrangements, each with unique advantages and risks. Understanding the relative risks and benefits of each of the potential alternatives is critical in making the right outsourcing decision.

2.2.2 Why organizations outsource

In this section, overview of previous academic works on outsourcing is given and is aimed to identify reasons for outsourcing.

Table 2.1 gives an overview of the main reasons as established by five previous studies (P-E International 1994 (also Szymankiewicz 1994); Boyson *et al.* 1999; Fernie 1999; van Laarhoven *et al.* 2000; Penske Logistics 1999). Since different studies use different wording to refer to generically same or similar reasons, the first column is classificatory, indicating the area.

The table includes double ranking. First, authors of the cited studies ranked the reasons. Second, for the purpose of this research, an overall ranking was calculated. This was done by awarding ten points to the top reason identified by each author, eight points to

the second highest reason, six to the third, five to the fourth and four to the fifth. For each of the studies, ranking 1 before a reason means that the largest share of companies surveyed claimed that particular reason to be their primary motivator for outsourcing, ranking 2 means that the second largest share of companies outsource for that reason etc. The points were summed up and are presented in the right-hand column.

The maximum score in Table I could be 50, in which case all five studies would have found the same reason to be the top driver for outsourcing. The table shows that cost reduction (40 points), improvement of service levels (27), increase in operational flexibility (26), focusing on core competencies (17), improvement of asset utilization (16) and change management (16) are the most common reasons for outsourcing.

Table 2.1: Reasons for outsourcing – summary of surveys

Type of reason	P-E International (1994): consumer goods industry	Boyson *et al.* (1999): all industries	Fernie (1999): retailers	van Laarhoven *et al.* (2000): wide range of industries	Penske Logistics (1999): several industries	Score
1. Cost or revenue related	3. Reduce costs	1. Cost saving or revenue enhancement	5. Trends to be more cost efficient	1. Cost reduction	1. Reduce Costs	**40**
2. Service related	2. Improve service levels		4. Provides more "specialist services"	2. Service improvement	3. Improved service levels	**27**
3. Operational flexibility related	1. Flexibility		1. Provides more flexible system	3. Strategic flexibility		**26**
4. Business focus related	5. Non-core activity	2. Outsourcing non-core business		4. Focus on core		**17**
5. Asset utilization or efficiency related			2. Allows financial resources to be concentrated on mainstream business		2. Increased efficiency	**16**
5. Change management related		4. Re-design or reengineering the supply chain		5. Change implementation	4. Overall improvement of distribution	**16**
7. 3PL expertise related			3. Exploits management expertise of contractors			**6**
7. Problem related		3. Outsourced area was a major problem for the company				**6**
9. Investment related	4. Avoid investment					**5**

The literature review showed that costs are the single most common reason for outsourcing.

However, according to Wilding (2004), consumer goods companies choose to outsource primarily in order to benefit from the competencies of 3PLs. Flexibility and cost objectives are very important too but cost reduction is definitely not an uncontested leader. There are several reasons why so few firms outsource for cost reasons:

i. Primary business focus is on service, rather than cost. Of the four main drivers for outsourcing (3PL competencies, cost, flexibility and focus on core), only one is cost related. The other ones are directly or indirectly service-related, showing that service considerations dominate over cost ones. It may be argued that outsourcing decisions in the consumer goods logistics tend to be less cost-driven than they are on average over all industries.

ii. Costs are a qualifying, not a winning factor. Companies assume low costs from 3PLs and make outsourcing decisions on other grounds, such as service. Szymankiewicz (1994) even suggests that grocery retailers take both low cost and good service from 3PLs for granted.

iii. 3PLs' ability to actually lower logistics costs. Our evidence suggests that consumer good companies are aware of the fact that not every outsourcing decision decreases costs and therefore they do not expect cost cuts in the first place. A profit margin charged by 3PLs is reflected in the price for the services and may mean that keeping logistics in-house is cheaper than outsourcing.

According to Wilding's survey, some survey respondents outsourced for alternative reasons that had not been included in the list. Two firms outsourced to solve capacity problems. One company was motivated by a major organizational change (de-merger) and another one was looking to find synergy with the 3PL.

Bendor and Samuel (1998) assert that outsourcing provides a certain power that is not available within an organization's internal departments. This power can have many dimensions: economies of scale, process expertise, access to capital, access to expensive

technology, etc. Another possible benefit is that outsourcing provides companies with greater capacity for flexibility, especially in the purchase of rapidly developing new technologies, fashion goods, or the myriad components of complex systems (Harrison 1994; Carlson 1989).

On the other hand, as the world becomes more globally integrated and the boundaries between countries and cultures disappear, many developing countries, including Turkey, are turning into attractive centers for international firms because of their geographical locations, low working fees and high potential for market extensions. However, the study shows that in Turkey, outsourcing is still solely based on transportation (Uluengin & Uluengin 2003). According to Aktas and Uluengin (2005, p. 317); many Turkish firms understand logistics services as taking the transportation order from the manufacturer and delivering the goods to destination points, without thinking about the warehouse design, the optimum location of the warehouse or of inventory management. Such ways of thinking are concerned only with one side of the subject and reduce logistics services to a narrow transportation perspective.

2.2.3 Critical success factors of outsourcing

In order to ensure the success of using contract logistics, certain additional factors are to be considered during and after the implementation of the outsourcing process. The first and foremost is that decision to outsource must come from the top. Communication between logistics users and providers (Bowman 1995; Andel 1994; McKeon 1991; Trunick 1989), which is essential for the coordination of internal corporate functions and outsourced logistics, is also a very important factor in this respect. Firms need to specify clearly to service providers their role and responsibilities as well as their expectations and requirements.

Internal communication is also equally important. It has been asserted that managers must communicate exactly what they are outsourcing and why – then get the support of every department (Bowman 1995). Richardson (1990) and Maltz (1995) also emphasize the importance in educating management of the benefits of contract logistics. Management needs to be convinced to try outsourcing and view it as a strategic activity.

Success of outsourcing depends on a user-provider relationship based on mutual trust and faith (Bradley 1994). This does not imply that control measures are redundant, firms should mandate periodic reporting by the service providers (Distribution 1995; Richardson 1990). The need to select third parties wisely and maintain control while building trust is very important (Richardson 1994). Any deal must be tied to internal controls that link all payments to invoices, bills of lading, or purchase orders (Bradley 1994). A crucial aspect of successful outsourcing linking to trust is that users ought to be willing to part with proprietary information, which can help a capable third party to reduce total logistics costs (Bowman 1995). On the other hand, service providers have the responsibility and obligation to protect users' sensitive data on products, shipments and customers (Distribution 1995).

According to Richardson (1990), there are several other critical factors that make outsourcing work. They include focus on the customer; establishing operating standards and monitoring performance against those standards; knowing the payback period, benefits expected by the firm, and the means to achieve those benefits. Factors, such as being aware that outsourcing may require a longer term of service than the firm is used to and building information systems that will allow the firm to make ongoing cost/value comparisons, are also critical. However, for McKeon (1991) understanding each other's cultures and organizational structure to ensure a good match, and knowing logistics strategy, i.e., understanding the logistics function's role in meeting the business objectives of the firm (e.g. differentiation or low cost) are the most important factors for successful outsourcing. The business objectives of the firm may dictate the extent to which it will use partners: outsource a single function or outsource all key functions.

The importance of the human factor in outsourcing also cannot be undermined. The firm must involve the people currently providing the logistics service since their expertise enables them to facilitate the transition from in-house logistics to third-party logistics. Furthermore, they must be given an opportunity to move with the function if outsourcing is implemented, proving how valuable they can be. However, there is the risk that the fear of getting retrenched due to outsourcing of a function may prompt current employees to sabotage the process (Maltz 1995).

The success criteria needed to establish sustainable partnerships in the area of contract logistics are the various relationships between the people involved. Open and honest environment, key management, coherent and effective internal measurement systems, mutual respect and empathy, commitment to investment, and financial and commercial arrangements are of particular importance in this aspect.

For Razzaque (1998, p. 101), it is evident that, to make contract logistics work, a high level of commitment and resolution is needed on the part of the buying firms. Management must examine critically each of these success factors to determine how they can be put into practice. Only then firms can truly harness the benefits of outsourcing and to develop long-term partnerships that manifest the many advantages that are possible with the use of third-party logistics.

2.3 Logistics Outsourcing

After having introduced logistics and outsourcing, the question arises how to organize logistics processes on the level of the individual firm. The options for the firms are to either operate them by themselves or to partially or completely outsource them to a third party in the form of a logistics service provider (LSP).

The following chapter will first highlight the origin of logistics outsourcing and provide a definition, before looking into its benefits and risks. Then, the different kinds of logistics service providers available for outsourcing arrangements are introduced. Finally, an extensive literature review will provide the basis for the identification of research needs which will be addressed in this work.

2.3.1 Origin and definition

Logistics capabilities are an important source of competitive advantage. As described before, the configuration of the individual logistics processes depends largely on the current phase of logistical development. At the same time, the question arises which parties are involved in the formation and realization of the processes.

When approaching the concept of logistics outsourcing, Razzaque and Sheng (1998, p. 89) offer some valuable insights. According to them, a company can basically choose

between three different options to handle its logistics activities effectively and efficiently:

i. It can provide the function in-house by making the service

ii. It can either set up an own logistics subsidiary or buy a logistics firm

iii. It can outsource the service and then buy the service from an external provider.

The issue of outsourcing logistics services has received widespread attention over the last 15 years (Razzaque & Sheng 1998; Cooper 1993; Virum 1993; Bardi & Tracey 1991; Sheffi 1990; Bowersox *et al.* 1989). In the early discussion, different views of the meaning of logistics outsourcing became apparent. Lieb *et al.* (1993) suggested that outsourcing, third-party logistics and contract logistics generally mean the same thing. Bradley (1994) pointed out that service providers must offer at least two services that are bundled and combined, with a single point of accountability using distinct information systems which is dedicated to and integral to the logistics process. This is contrary to the view of Lieb *et al.* (1993, p. 35) who note that outsourcing *"may be narrow in scope"* and can also be limited to only one type of service such as warehousing.

After the initial dissension on the scope required to justify the use of the term "*logistics outsourcing*" more general definitions have been accepted. Lambert *et al.* (1999, p. 165) state that logistics outsourcing is *"the use of a third-party provider for all or part of an organization's logistics operations"* and add that its utilization by the firms is increasing. Rabinovich *et al.* (1999, p. 353) define logistics outsourcing relationships even more broadly as *"long and short-term contracts or alliances between manufacturing and service firms and third party logistics providers"*. For this work, logistics outsourcing will be understood in line with the definition provided by Lambert *et al.* (1999), while the focus will be on the contract logistics described by Rabinovich *et al.* (1999).

The outsourcing trend has been continuously growing over the last years. It has been following the changes that have also been inducing the four phases of logistical development as presented in chapter 2.1.1. According to different authors such as

Trunick (1992), Sheffi (1990) another important driving force behind this has been the increasing globalization of business. The continuously growing global markets and the accompanying sourcing of parts and materials from other countries has increased the demands on the logistics function (Cooper 1993) and led to more complex supply chains (Bradley 1994, p. 49). The lack of specific knowledge and suitable infrastructure in the targeted markets forced firms to turn to the competence of logistics service providers. In recent years, the outsourcing trend has gained even more momentum as the consensus in firms formed that the utilization of a logistics service provider generally can reduce the cost of logistics processes and can increase their quality (Lambert *et al.* 1996, pp. 2-5).

Logistics service providers (LSP) suitable for providing these services today exist in abundance, reacting to the ever increasing demands of the customers and the subsequently developing markets. Due to the fact that a number of firms do not view logistics as a core competency or even if they do, are willing to outsource them to a third party, outsourcing has become a relevant option. However, since the needs differ in every individual case, Wallenburg (2004, p. 46) argues that every firm must answer two important questions before actually outsourcing:

i. Which part of logistics shall be outsourced?

ii. Who shall provide the service?

2.3.2 Benefits and risks of logistics outsourcing

Essential for answering the question regarding the optimal outsourcing scope are the resources of the respective firm and alongside the trade-off between consequential advantages and disadvantages. This will vary according to the individual firms' perception of the benefits and risks associated with the particular outsourcing arrangement. Although they are inherently different, some aspects commonly associated with logistics outsourcing shall be presented in the following chapters.

2.3.2.1 Advantages of logistics outsourcing

The most frequently mentioned benefit of outsourcing is the reduction of the firm's logistics costs (Browne & Allen 2001, p. 259; Bardi & Tracey 1991, pp. 15-21). This

can become manifest in several different ways: Bradley (1994) points out that logistics service providers can be more efficient than a manufacturer, because logistics is their core business. Hence, specialization effects and the proper utilization of core competencies lead to lower production costs. Furthermore, inefficiencies which have not become apparent as long as the service was produced in-house and therefore was not subject to competition are eliminated (Wallenburg 2004, p. 47).

Lower production costs can also be achieved through economies of scale and scope resulting from the larger volumes of similar or equal logistics services a LSP produces and through the higher utilization ratio of the assets employed. Furthermore, logistics service providers can balance varying demand patterns better than a single manufacturing firm by diversifying their customer portfolios and reduce labor costs by benefiting from lower wage levels compared to those in manufacturing industries.

Logistics outsourcing also directly affects the cost position of a firm due to a reduced need for capital investments. Richardson (1990) points out that investments in facilities can be reduced while Sheffi (1990, pp. 27-39) states that costly information technology expenditures can be saved when outsourced to a logistics service provider. Beyond that, logistics outsourcing also allows for a decrease of the workforce and the associated investments.

The effects mentioned above stemming from the reduction of capital investments ideally allow a firm to source only the required logistics services and to thus convert the formerly fixed costs of the logistics capacities into variable costs. Besides all theses different potentials of cost reduction, however, logistics outsourcing has some further benefits for the firm. Especially in recent years the realization has spread among firms that outsourcing logistics can also lead to improvements in logistics performance that in-house could not be achieved. Among these improvements are the following:

As a result of outsourcing, the expertise, technology, and infrastructure of the LSP can be utilized (Browne & Allen 2001, pp. 259-260). This can lead to a higher logistics performance in multiple dimensions. Lalonde and Maltz (1992, p. 3) identify higher quality, better service, optimized asset use, and increased flexibility. Multiple authors

go into further detail, such as Richardson (1990) who mentions faster transit times, less damage, and improved on-time delivery.

The increased flexibility is a major benefit for firms. It allows firms to become more responsive as the needs of the market or customers change, as the LSP contributes by supplying its know-how and existing resources (Browne & Allen 2001, pp. 259-260).

At the same time, the firm is enabled to concentrate on own core business and its core competencies. This is particularly significant with respect to the core competence debate suggesting that due to limited internal resources and a growing complexity of the market competitive advantage cannot be attained in all areas simultaneously and focusing is necessary. Outsourcing logistics to a service provider allows for this concentration on core competencies, reduces the complexity of the firms' business processes and consequently facilitates sustainable competitive advantage.

Furthermore, outsourcing reduces both the strategic and the operative risk of the firm. The strategic risk in the form of investment decisions in assets is outsourced, as well as operative risks, e.g. missed deadlines, unexpectedly surging costs or quality problems in the logistics processes, which all now have to be borne by the LSP.

Another factor whose importance varies according to the corporate context and the business environment is mentioned by Lynch (2000, pp. 9-11), who points out that labor considerations must not be neglected when making the outsourcing decision. Problems with the workforce, originating e.g. from a high rate of unionization (USA) or particular labor agreements concerning wages can be passed on to the LSP.

2.3.2.2 Disadvantages of logistics outsourcing

After the initial outsourcing debate had a rather euphoric notion, realization came over the years that outsourcing is accompanied by some disadvantages and risks (Wentworth 2003, pp. 57-58; McIvor 2000, pp. 22-23).

One of the most commonly cited risks is the loss of control (Wentworth 2003, pp. 57-58; Bardi & Tracey 1991), paired with the dependence on an LSP of ten accompanying the relationship. The firm must rely on the LSP to fulfill the service as agreed upon in the contract, but then depends on the LSP as the very source for the data it needs for

judging whether the levels of quality and service have been achieved or not (Wentworth 2003, p. 57). The same holds true for the LSP's truthful declaration of the costs incurred when rendering the logistics service, which frequently is the base for the price charged to the firm. This effect is aggravated in the case that a firm outsources the entire logistics function, thereby losing its internal logistics skills and hence its capabilities to judge the outsourcing performance. That can be the origin for opportunistic behavior on the side of the LSP. If the firm wants to limit the potential for opportunistic behavior, it must install control mechanisms. These will produce transaction costs such as bargaining and control costs, which must be added to the overall cost when making the outsourcing decision.

It has been pointed out in the previous chapter that outsourcing can reduce the complexity of business processes, enabling the firm to concentrate on its core business. It must be noted, however, that in the relationship with the LSP coordination efforts between the parties are necessary, adding some other form of complexity (Wallenburg 2004, p. 48), which, depending on the context of the relationship, could turn into a serious obstacle enroute to successful outsourcing.

Other authors point to the complexity of outsourcing projects as one immanent and significant disadvantage. According to McIvor (2000, pp. 24-26), the strategic dimension of outsourcing projects is often neglected, leading to sub-optimal results based on the short term reasons of cost reduction and capacity issues. He concludes that problems frequently occur because complex issues, such as a formal outsourcing process, an adequate cost analysis and a thorough definition of the own core business have not been paid sufficient attention.

2.3.3 Balance Sheet Impact of Logistics Outsourcing

To illustrate how these issues can impact the financial status of a firm, the following example is provided from a current discussion on logistics outsourcing. Referring to Table 2.2, consider a company that is achieving a 5 percent return on sales, a 10 percent return on assets and a 25 percent return on equity. Logistics can affect both the income statement and the balance sheet. While sales can be increased by virtue of improved customer service and a stronger customer interface we will not assume an increase in

sales in this example. However, the following results are typical. Specifically, managing inbound warehousing and transportation can reduce the cost of sales, typically by 1-3 percent. Distribution expenses are reduced by 3-7 percent when a TPL's expertise tightens control and increases efficiency. A 20-30 percent decrease in inventory cost levels can be found when the facility network is optimized and precise inventory methods are used. Finally, property and equipment assets will be reduced 5-10 percent by eliminating unneeded facilities or avoiding building new ones.

Table 2.2: Balance Sheet Impact of Logistics Outsourcing

	Before Outsource	**After Outsource**		**Before Outsource**	**After Outsource**
Profit and Loss	**$**	**$**	**Balance Sheet**	**$**	**$**
Sales	100,0	100,0	Current Assets		
Cost of Sales	70,0	69,0	Cash	1,0	1,0
Gross Profit	30,0	31,0	Inventory	17,0	13,0
Operating Expenses			Accts. Receivable	7,0	7,0
Distribution	8,0	7,5	Total	25,0	21,0
Selling and Admin	12,0	12,0	Prop. And Equipment	25,0	24,0
Total	20,0	19,5	Total Assets	50,0	45,0
Operating Income	10,0	11,5	Liabilities and Stockholders Equity		
Interests and Taxes	5,0	5,5	Liabilities	30,0	25,0
Net Income	5,0	6,0	and Debt Equity	20,0	20,0
			Total	50,0	45,0

When you combine these improvements, a great deal of financial leverage appears. In this example, return on sales increases 20 percent, from 5 percent to 6 percent. ROA improves from 10 percent to 13,2 percent, a 32 percent increase. ROE increases to 30 percent, a 20 percent improvement. This example shows that the effects of logistics outsourcing go beyond simply reducing costs.

2.3.4 The role of logistics service providers in logistics outsourcing

Logistics outsourcing is enabled by a broad range of logistics service providers. In line with Bhatnagar *et al.* (1999, p. 570), in this work the term logistics service provider (LSP) will refer to an outside provider employed by firms to perform some or all of its logistics activities. LSPs differ considerably in the scope and depths of services offered. Due to their special relevance for the topic, the most important forms of LSPs will be presented in this chapter.

The market for logistics services can be segmented along the lines of the four phases of logistics development introduced in chapter 2.1.1. The services offered by the LSPs are adapted to the needs of the respective customers. They range from a narrow spectrum, mainly consisting of warehousing and transportation services, for customers of the primal phases to integrated service portfolios including a multitude of different services for the advanced phases. Altogether, five kinds of LSPs can be distinguished: carriers, freight forwarders, courier & express & parcel/postal providers (CEP), third party / contract LSPs (3PLs) and fourth party LSP (4PLs).

The above mentioned logistics service providers can be hierarchically classified depending on their service portfolio. *Carriers* typically own logistics assets and concentrate mainly on supplying transportation services. They are mostly confined to either road, sea, air or rail transportation and only in few cases also offer combinations of these services. They receive their orders either directly from the customer or through a *freight forwarder* and with their service portfolio cater to the needs of traditional logistics of the first phase of logistics development.

With increasing sophistication of logistics processes, *freight forwarders* address the growing needs of the customers by offering coordinating functions and intermediating services. They bundle transportations services, offer warehousing and in increasingly also supply a combination of the two. While the focus of the *freight forwarders'* services is still on providing physical processes, they also carry out additional services such as transportation planning and management including providing the associated information systems and also sometimes act as *carriers* by using own asset for

transportation or warehousing. Overall, *freight forwarders* in their coordinating function address the needs of firms which are located in the second phase of logistics.

The third phase of logistics development requires logistics to enable inter-organizational flow and process orientation and therefore demands comprehensive logistics solutions. During this phase, solution providers in the form of *CEP* and *3PLs* depending on the needs of the customers be come increasingly important. For customers aiming at end customer distribution services, the *CEP* offer integrated services that ensure the distribution of small units to any destination, often with time-critical shipments. *3PLs* or *contract LSPs* focus on business customers and provide service packages that carried out on a longer term contractual basis. The solutions commonly include several services, such as warehousing, pick&pack or order handling. Increasingly, *3PLs* also provide more customized services integrating into the customer's value chain, such as fleet management, order handling, complaints management, or assembly services. For parts of the services offered that the *3PL* could not provide alone, due to a lack of own assets, frequently *carriers* or *freight forwarders* are employed.

The above mentioned logistics service providers, concentrating on complex, long term contract based logistics solutions, are in the focus of this work. Since the terminology varies considerably even beyond *3PL* and *contract LSP*, they will in the following be called *logistics service providers (LSPs)* as both terms meet the requirements of the definition presented above provided by Bhatnagar *et al.* (1999, p. 570) following which an LSP is employed by "*an outside company to perform some or all of the firm's logistics activities*". Consistent with Berglund *et al.* (1999, p. 59), LSPs in the context of third party logistics offer

> *[…] activities […] consisting of at least management and execution of transportation and warehousing […]. In addition, other activities can be included […]. Also, […] the contract [is required] to contain some management, analytical or design activities, and the length of the cooperation between shipper and provider […] [must] be at least one year […]".*

All relationships between LSPs and their customers analyzed in the latter must fall under this definition in order to adequately distinguish between advanced logistics outsourcing relationships and traditional "*arm's lengths*" sourcing of transportation and/or warehousing.

Offering services beyond those mentioned above are the *4PL-Providers*. Even though this term is still utilized inconsistently, *4PL* refers to a logistics service provider which serves as an intermediary and general contractor for inter-organizational supply chains without supplying any physical process by itself. Rather, it employs *carriers*, *CEPs,* or other *LSPs* for the physical processes and concentrates on planning, conceptualizing and managing the supply chain. It therefore is virtually operating without physical assets and therefore supposedly is neutral.

2.3.5 General logistics outsourcing perspective in Turkish firms

According to Büyüközkan *et al.* (2007), in 2006, the logistics sector amounted to $50 billion market in Turkey and is expected to attain a $100 billion market in 2010. In the period 2004–2005, firms having revenue larger than $100 million have grown over 50 percent and the remaining ones approximately 25 percent. These rates have increased even more in 2006. The main motivation behind this spectacular growth was the increased import–export figures, with 230 percent in the total foreign trade volume in the period 2000–2005. The leading articles in exports were road vehicles and their parts, apparel and clothing accessories, machineries, electrical and mechanical appliances, equipments and parts, iron ore and steel, whereas in imports mineral fuels, lubricants, and related materials took the first place. A total of 53 percent of the export is made with road transportation and with its approximately 40,000 trucks; Turkey has the largest fleet in Europe.

For foreign companies, it is a profitable investment to acquire a small Turkish company with its customers, to merge business capacities and increase the efficiency. While attracting large companies with its potential, it is expected that the number of mergers and acquisitions will be increased. In the near future, Turkish logistics firms are targeting to develop in the markets located in Iran, Azerbaijan, and Middle East. Although there exist hundreds of small to large firms in the sector, the big share is distributed among 200 firms, in which only 20 percent are mergers with foreign companies. The number of leading companies of the sector is not larger than 20. Companies operational in all logistics activities are even less. Recognizing the geographical importance and growth potential of the logistics market, many well-known logistics firms such as DHL, FedEx, UPS, and TNT have invested in Turkey.

2.3.6 Logistics outsourcing researches

After the different kinds of logistics service providers have been introduced, in the following the status quo of logistics outsourcing research will be presented.

As the previous chapters have shown, the scale and scope of logistics outsourcing has been steadily growing over the last decades, creating markets of significant sizes and consequently creating opportunities for firms which find themselves under ever increasing pressure to lower costs and increase logistics performance. An end of the trend is not in sight. Therefore, a high relevance of research in logistics outsourcing and its success factors can be assumed.

It therefore does not come as a surprise that Mentzer and Kahn (1995, p.242) find "that logistics research is a growing and viable research area" by investigating the development of articles published in the Journal of Business Logistics between its inauguration in 1978 and 1993. However, they formulate substantial criticism on the quality of the overall empirical logistics research conducted in these early years.

According to Mentzer and Kahn (1995, pp. 240-244) more than 53 percent of the existing research is normative in nature and does not have empirical content. 36 percent of the research includes case studies only and a mere 4 percent involves hypothesis testing. According to Mentzer and Kahn (1995) this is urgently needed for subsequent theory development and testing and is the main driver of successful logistics research. They conclude that as of 1995, the few studies that have included hypothesis testing procedures have mostly not stood up to scientific rigor. Commonly, they fail to provide information on the reliability and validity of the data while at the same time the statistical methods being utilized are limited in most cases to regression or correlation analysis. According to Engelbrecht (2004, pp. 28-29), the situation has not changed significantly until 2002. Therefore, the argument of Mentzer and Kahn (1995, p. 244) still prevails which demands a more rigorous and scientific approach including more hypotheses: "If the discipline is to become more theoretically rigorous, it must progress through the framework and thus pursue more hypothesis testing studies. While many researchers would prefer to pursue only exploratory research because of the flexibility in topic selection, ease of data analysis, and less meticulous rigor, a maturing scientific

discipline mandates a shift toward greater hypothesis testing, more rigorous date analysis, and standard discussions of validity and reliability".

According to Wallenburg (2004, p. 52), logistics research has always shown a strong practice-orientation. In earlier years the focus was on functional specialization, targeting almost exclusively individual competencies and local optimization potentials. Most commonly, the research reflected the view and interests of a single firm only. In recent years, the focus has shifted towards the entire supply chain and factors of collaboration that enable the optimization of entire process-chains rather than isolated processes.

Overall, logistics research has traditionally been confronted with numerous operative and practical problems (Wallenburg 2004, p. 52), requiring quick and efficient solutions. By adhering to this need, it remained rather conceptual and – in the few empirical works – mostly qualitative. Thus, it does not come as a surprise that logistics research has also recently been criticized for its lack of quantitative empirical research (Garver & Mentzer 1999, pp. 33-34).

While the shortcomings portrayed above are valid for the broad field of contemporary logistics research and the studies explicitly targeting logistics outsourcing are still scarce, a slow change towards more research in that area and a more rigorous scientific approach as demanded by Mentzer and Kahn can be observed. Since the research until 1999 has already been summarized in great detail by several articles (Murphy & Poist 1998; Razzaque & Sheng 1998), the following section will concentrate on the evolving research published since 1999.

The studies between 1999 and parts of 2003 (Bhatnagar *et al.* 1999; Boyson *et al.* 1999; Van Laarhoven *et al.* 2000 etc.) offer very valuable insights into logistics outsourcing, but must in large parts be subject to the same criticism as voiced by Mentzer and Kahn (1995, pp. 240-244) . They are largely descriptive in nature, the only exception being Boyson *et al.* (1999) who also perform an ANOVA analysis for selected questions. None of the studies involve hypothesis testing procedures. Findings include that the understanding of the meaning of logistics outsourcing for achieving competitive advantage is increasing, that cost reductions and logistics performance increases are the

most significant motivators for the outsourcing decision, and the considerable importance of the relationship formation for the project's success.

Researches between 1999 and 2002 can be summarized as follows (see also Appendix A.1):

Research by Bhatnagar and colleagues (1999) discussed the findings from a survey of logistics outsourcing among Singaporean firms. The most common activities to be outsourced include shipment consolidation, order fulfillment and carrier selection; cost savings, customer satisfaction, and flexibility (customization) were the most important reasons for logistics outsourcing. Although over 90 percent of the responding organizations expressed satisfaction with the performance of their 3PL providers, over two-thirds reported difficulties in implementing the 3PL concept.

Sum and Teo (1999) used Porter's competitive strategy framework to examine selected characteristics of Singaporean 3PL providers. Their findings indicated that those 3PL companies following a "cost and differentiation" strategy consistently exhibit stronger performance metrics than do other strategic types.

According to Boyson *et al.* (1999), the outsourcing of logistics functions has proven to be effective in helping U.S. firms to achieve competitive advantage, improve their customer service levels and reduce their overall logistics costs. They assert that maintaining an internal capability to manage the logistics outsourcing process was a critical issue. Additionally, their findings suggest that firms should take a strategic approach involving long-term goals rather than outsourcing on a function by function basis.

Skjoett-Larsen (2000), using case studies, reinforced the notion that relatively new concepts, such as third-party logistics, are often characterized by multiple definitions. Their research suggests that two theories, involving transaction costs and the network approach help explain the development of 3PL.

Van Laarhoven and colleagues (2000) discussed the results from a European 3PL study that updated research conducted in the early 1990s. In general, 3PL continues to be regarded as a successful undertaking, and most 3PL customers express relatively few

complaints about their 3PL experiences. Moreover, "highly successful" 3PL relationships exhibit several distinct characteristics from less successful relationships, such as a stronger emphasis on performance metrics.

Research by van Hoek (2000) argued that traditional third-party logistics services such as warehousing and transportation have become, to some extent, commoditized. Because the profit margins and returns on these services are marginal, 3PLs might consider providing supplementary services, particularly those associated with mass customization and postponement. Telephone surveys of Dutch logistics service providers discovered that while some currently offer various supplemental services, these companies tend to be the exception rather than the rule.

A study by Lewis and Talalayevsky (2000) examined how the evolution of information technology has allowed the largest users of logistics services to focus on their core competencies and contract out logistics. Additionally, they discussed how significant improvements in information technology supported centralized markets, such as those offered by 3PLs, becoming increasingly feasible.

Persson and Virum (2001) discussed two studies financed by the Norwegian Research Council. Their article describes some of the major findings in these studies on growth strategies for logistics services providers. In particular, the research suggests that given the pressures in the industry and the individual strategic position, the strategic choices are limited, leading to some dominating strategic directions.

Bolumole (2001) examined 3PL relationships within the U.K. petrol industry. This research suggests that the capability of service providers to facilitate supply chain solutions is largely influenced by four main factors, which in turn significantly determine their role in the supply chain. These factors include: (1) the strategic orientation of the outsourcing organization; (2) its perception of service providers' role within logistics strategy; (3) the nature of the client-provider relationship; and (4) the extent to which the logistics process is outsourced.

Research by Stone (2001) studied the approaches that U.K. logistics service providers have used to implement expansion within the single European market. The study found

that expansion has proved demanding and, for many U.K. logistics service providers, the single European market has yet to fulfill its initial promise.

Lieb and Miller (2002) examined the use of third-party logistics services by large U.S. manufacturers. They found that the use of these services has reached an all-time high and users of these services are generally well satisfied with the impact of 3PL services on their companies. Additionally, the research suggests that users are most satisfied with the impact of these arrangements on logistics costs, logistics service levels and customer service.

Research by Larson and Gammelgaard (2002) focused on Danish logistics service providers. Their findings suggest that Danish logistics providers tend to be "niche firms," focusing on the domestic market and limited sets of customers by industry. They also found considerable use of functional subcontracting in the logistics industry, particularly with respect to the transportation function.

The most serious shortcomings of the research until 2002 are the lacking proof for the how to select logistics service provider with a quantitative way and how to measure performance of logistics outsourcing. The descriptive and yet in parts normative studies presented above have failed to show with the adequate scientific rigor that logistics outsourcing does increase logistics performance and at the same time have not been able to identify the success factors for logistics outsourcing with advanced statistical methods.

This is starting to change in 2002 with the works of Andersson and Norman (2002), Knemeyer *et al.* (2003), Stank *et al.* (2003), Knemeyer and Murphy (2004) and Engelbrecht (2004).

Engelbrecht (2004, pp. 244-250) shows in a partial model, using structural equation modeling (SEM) to test his hypotheses, that the degree of outsourcing can explain 8 percent of the logistics cost position of a firm. The hypothesized direct effect of the degree of outsourcing on the level of logistics services turns out to be non-significant. These findings indicate for the first time on a high statistical level that the descriptive studies of the past, which have normatively assumed the performance effect of logistics

outsourcing, were right in their assumption, even though their research procedure may have been lacking the adequate scientific rigor. Nevertheless, the explanatory value of the degree of outsourcing is quite low. It must therefore be assumed, that the true drivers behind logistics outsourcing performance as yet remain to be identified.

An important contribution to this discussion is made by Knemeyer *et al.* (2003). They employ SEM to show that the benefits of developing closer relationships between customer and the LSP can justify the accompanying increasing costs. This is of particular interest since Stank *et al.* (2003, pp. 41-45) show that relational performance of the LSP is the single most important factor in obtaining customer satisfaction, which in turn can be understood as an expression of the achievement of the goals previously set for the outsourcing project. In a recent study, Knemeyer and Murphy (2004, pp. 45-46) furthermore demonstrate by using SEM that various relationship marketing dimensions, such as trust, communication and opportunistic behavior, influence the buyers perception of the logistics service providers' performance and thus are relevant factors influencing the outsourcing performance.

The findings presented above suggest that the degree of outsourcing alone cannot explain the performance effects of logistics outsourcing. The main driver must lie somewhere else. Recent studies have proposed that the formation of the relationship between the buyer and the LSP is one of the main drivers (Knemeyer & Murphy 2005; Langley *et al.* 2005; Knemeyer & Murphy 2004; Stank *et al.* 2003). However, as yet no model has been developed that would encompass all relevant dimensions and factors of relationships. Furthermore, it remains to be shown which performance effects the individual constructs of the model would have and which dependencies inside the model would exist. All these different findings are needed to further advance research in this field and to develop feasible recommendations for everyday management.

The role of the context of the firm in the logistics outsourcing context is explained by Chow *et al.* (1994) and Pfohl and Zöllner (1997). It is virtually impossible to make a generalized and universally valid recommendation for the outsourcing decision. In fact, it is crucial to first investigate the context of the firm in order to determine what is outsourced to whom. To determine what outsourcing strategy has primacy in which context, Chow *et al.* (1994, p. 26) suggest the use of contingency models of logistics

performance which should include factors such as the environment, the product line or the production technology.

A last open question of utmost importance is a methodology for the selection of a logistics service provider. Many authors, in refereed journals and websites, have come out with their suggestions on logistics outsourcing. For example, Andersson and Norman (2002) have suggested an eight-point plan for the selection and implementation of logistics outsourcing services. These points include (i) define or specify the service, (ii) understand the volume bought, (iii) simplify and standardize, (iv) market survey, (v) request for information, (vi) request for proposal, (vii) negotiations, and (viii) contracting. Many other authors have highlighted the importance of these points. For example, Bhatnagar *et al.* (1999) have observed that by developing goals and selection criteria, user companies will be in a better position to determine which provider would best suit their needs. In this regard, Van Hoek (2000) has stressed the need for further research in the outsourcing of logistics services. Sink and Langley (1997) have stressed the need of a sound decision-making procedure in the selection of a provider. In many cases, after initial screening the final selection of a provider becomes a tough task. Although many companies and consultants use the methods that are similar to that suggested by Andersson and Norman (2002) a well-defined comprehensive methodology that systematically incorporates all the relevant criteria in logistics outsourcing is still awaited.

In recent years, the quantitative models for selection of logistics service provider have introduced into literature. For example, Jharkharia and Shankar (2007) proposed methodology serves as a guideline to the logistics managers in outsourcing – related decisions. Jharkharia and Shankar used ANP method to select provider. The ANP approach is capable of taking into consideration both qualitative and quantitative criteria. The ANP approach illustrated in their research has a few limitations as well. For example, the outcome of the model is dependent on the inputs provided by the logistics manager of the case company. Also, in real life, each of sub-criteria can not determine with exact number which means that they are ambiguous.

2.4 Selection of Logistics Outsourcing Company (3PL)

Strategic alliances are an important form of interorganizational co-operation that has received much coverage in the literature (Gebrekidan & Awuah 2002). By forming strategic alliances, the partners can pool their resources and strengths together in order to achieve their respective goals, share risks, gain knowledge, and obtain access to new markets (Carayannis *et al.* 2000; Doz & Hamel 1998).

The proliferation of strategic alliances has been increasing in the last decade across logistics sectors (Wong *et al*. 2000; Mehta *et al.* 2006). Three most important types of logistics value chain-related strategic alliances have attracted interest among the researchers: third-party logistics (3PL), retailer– supplier partnerships, and distributor integration (Simchi-Levi *et al.* 2003). This research focuses on the first theme. 3PL involves the use of external companies to perform logistics functions that have traditionally been performed within an organization (Lieb *et al.* 1993). The functions performed by the third party can encompass the entire logistics process or selected activities within that process. The significance of an alliance between enterprises and 3PL depends on the following factors (Ballou 1999; Yan *et al.* 2003):

i. Utilizing the resources and capability of 3PL to acquire the scale benefits of logistics operation by reducing the enterprises' own logistics cost and transaction charge;

ii. Making use of 3PL's professional capability and agility to improve the overall operating efficiency and level of customer service in the supply chain;

iii. Reducing or avoiding the investment of enterprises' logistics establishment to give more resources for improving the enterprises' core competencies;

iv. Developing a credit base through the supplier alliance to cultivate a symbiotic relationship by increasing the overall competition advantage of each firm.

Thus, the 3PL evaluation and subsequent selection of a strategic alliance partner in a logistics value chain has an important strategic outcome to a firm to achieve superior competitive advantage.

According to survey done by the consulting firm, Accenture and Northeastern university, more than 65 percent of manufacturing companies in the U.S. outsource a portion of their logistics (Foster 2003). In fact, the outsourcing process is so commonplace that selecting a third party logistics company (3PL) is often handled like a routine purchasing decision. For a company like Huber Engineered Materials that views outsourcing as a strategic process, selecting the right 3PL is an exact process that focuses more on technology, operations and management skills than on cost (Foster 2003).

Despite their popularity in all business sectors, however, a significant number of alliances fail (Lee & Cavusgil 2006; Arino 2003; Dacin *et al.* 1997). Besides the inherent risk, one of the most often cited reasons is the incompatibility of partners for alliance failure. The choice of the right partner can yield important competitive benefits, whereas the failure to establish compatible objectives or communicate effectively can lead to insurmountable problems. Hence, the selection of a suitable partner for strategic alliance is an important factor affecting alliance performance in logistics value chain (Lee & Cavusgil 2006; Dacin *et al.* 1997). Finding the right partner requires careful screening and can be a time-consuming process. Developing an understanding of partners' expectations and objectives can also take time. However, many alliances are formed by chance meetings or through previous experience with the partner. While partner selection is an integral component of alliance success, very little research has devoted explicit attention to this issue. For this reason, the aim of this research is to propose an analytical approach to effectively select strategic alliance partners for the 3PL relationship.

Multiple criteria decision-making (MCDM) is a powerful tool widely used for evaluating problems containing multiple, usually conflicting criteria (Pomerol & Barba Romero 2000). This research models the 3PL selection problem as an MCDM problem, and presents a simple and selective approach to solve it. In addition, because subjective considerations are relevant to partner evaluation and selection decision, a fuzzy logic approach is adopted.

In the following two sections, the methods currently being used for the selection of a provider and specific problems related to the selection of a provider have also been captured.

2.4.1 Selection Methods

Analytical models for partner selection range from simple weighted scoring models to complex mathematical programming approaches. The most common approaches and methods for supplier selection include different Multi Criteria Decision Making (MCDM) methods such as AHP (Handfield *et al.* 2002) and analytic network process (Jharkharia & Shankar 2007), statistical techniques such as principal components analysis and factor analysis (Carr & Pearson 2002), data analysis techniques such as cluster analysis, discriminant analysis, data envelopment analysis (Liu *et al.* 2000), and intelligent techniques (Işıklar *et al.* 2007). In some researches, two MCDM methods can be combined, such as AHP and TOPSIS (Büyüközkan *et al.* 2008). In that study, the weights of evaluation criteria are determined through AHP and strategic alliances partners are selected by applying TOPSIS. Moreover, to ensure the proper reflection of evaluators' judgments by making reference to the uncertainty, they use fuzzy numbers to integrate linguistic assessments in their evaluation model.

The literature on partnership selection has been mainly qualitative and focuses primarily on methodological aspects (Meade *et al.* 1997). Only few research works are based on mathematical or quantitative decision-making approaches.

Kasilingam and Lee (1996) propose a mixed integer programming model for selecting vendors and determining order quantities. The model is cost-oriented and takes into consideration the costs of purchasing and transportation, the fixed costs for establishing vendors and the cost of receiving poor quality parts. Both fixed and variable costs are represented as an objective function and the problem is stated as an optimization problem, minimizing the cost function. However this model does not take into account qualitative criteria, since they cannot be represented as cost functions. The partner selection, as well as vendor selection decisions, requires various quantitative and qualitative criteria to be considered in the decision-making process.

The studies of Talluri *et al.* (1999) and Dean and Schniederjans (1991) are rather similar. They formulate the selection process as a multiple criteria decision-making problem and apply a mathematical modeling approach, based on a linear goal programming method. Unlike the previous method of Kasilingam and Lee (1996), these solution models take into account various selection criteria. However, the linear mathematical equations used in the goal programming optimization approach cannot represent adequately the specific features of the selection problem.

Babic and Plazibat (1998) employ multiple criteria analysis for ranking of enterprises, according to the achieved level of business efficiency. The authors demonstrate that the business efficiency is very complex and multidimensional concept; therefore, the multi criteria analysis could be the most suitable approach to the problem. Some business efficiency criteria are defined by relating individual forms of economic results and individual forms of economic sacrifice. However, all these criteria are quantitative, equivalent to the well-known efficiency indicators, used in the financial analysis, such as profit margin, return of investment, debt ratio, stock turnover, sale revenue per employee etc. In that study the Promethee method is used for final aggregation of the ratings of the enterprises regarding different criteria, while the importance of these criteria is determined by standard AHP pair wise comparisons.

Ossadnik (1996) proposes the use of the AHP method for allocating synergies to partners in a merger, according to impact intensities of their performance potentials on the synergistic effect. The paper concentrates on mergers in member states of the EC, under the premise that synergies are to be expected from such a transaction. Quantitative and qualitative criteria measuring the total synergy effect of synergy are given, such as the innovative power of the research department, liquidity reserves, distribution network, manufacturing equipment and the quality of the personal and managers. The standard AHP method is used to derive relative weights of the synergy components with regard to the total amount of the synergy effect and the impact intensities of the individual potential partners on the total synergy effect.

Narasimahn (1983), Nydick and Hill (1992), Partovi *et al.* (1989) also suggest the use of the AHP for vendor selection problems, because of its inherent capability to handle qualitative and quantitative criteria, its simple and understandable decision procedure

and the effective evaluation and selection process. The vendor selection problem is further discussed in Tam and Tummala (2001), who propose the application of the AHP in a group-decision making process.

Meade *et al.* (1997) employ the Analytic Networking Process (ANP) and the utility theory for justifying strategic relationships, driven by corporate strategies. The ANP is a general form of the AHP that does not require a hierarchical structure and unidirectional relationships between the decision elements. The relative importance of the criteria and alternatives is determined by pair wise comparisons, analogous to those used in the AHP. The methods of deriving priorities from pair wise comparison matrices are also identical. The authors identify some limitations of this approach, such as a time-consuming data acquisition process, requiring exact and precise data for the final evaluations. In the conclusion section, the authors propose some extensions that can be introduced to make that approach more robust.

Mikhailov (2002) presented a fuzzy approach to partnership selection in the formation of virtual enterprises. The AHP was extended to cope with the fuzziness when a decision maker compares the relative importance among attributes. Vanhaverbeke *et al.* (2002) provided an empirical analysis on external technology sourcing through alliances or acquisitions using a sample of strategic alliances and acquisitions in the application-specific integrated circuits (ADIC) industry. Chen (2003) investigated the effects of environment and partner characteristics on the choice of alliance forms by empirical analysis. Castellani and Zanfei (2004) examined how different aspects of multinational experience affect the choice of international linkage strategy by empirically testing the determinants of the choice between acquisitions, joint ventures, and strategic alliances for the world's largest electronics corporations between 1993 and 1997. Lin and Chen (2004) developed a fuzzy-decision-making framework to assist a company in selecting the most favorable supply chain to be allied with. Kumar, Vrat, and Shankar (2004) formulated a vendor selection problem as a fuzzy mixed integer goal programming model that included three primary goals, minimizing the net cost, minimizing the net rejections and minimizing the net late deliveries, subject to constraints including buyer's demand, vendors' capacity, vendors' quota flexibility, purchase value of items, budget allocation to individual vendor. Kumar *et al.* (2006) further developed a fuzzy

multi-objective integer programming approach for vendor selection problem in a supply chain. Amid *et al.* (2006) also solved a supplier selection problem in a supply chain by establishing a fuzzy multi-objective linear model by applying an asymmetric fuzzy-decision-making technique.

From the above literature review it can be concluded that the partnership selection process should be considered as a multiple criteria decision-making problem, rather than a pure mathematical modeling problem. The suitability of the classical AHP method, which is widely used for problems having multiple criteria and alternatives, is recognized by many researchers, working on the partnership selection problem.

All reviewed papers use the standard formulation of the AHP, where the pair wise comparison judgments are represented as exact numbers. However, in many practical cases the human preference model is uncertain and the decision-maker is reluctant or unable to assign exact numerical values to the comparison ratios. In the partnership election process the decision-making human agent is usually unsure in his level of preference due to incomplete and uncertain information about the possible partners and their performance. Since some of the decision criteria are subjective and qualitative, it is very difficult for the decision-maker to express the strength of his preferences and to provide exact pair wise comparison judgments.

In order to deal with such an uncertain evaluation problem, a modification of the AHP method is proposed in this research, which is based on interval representations of the comparison judgments, rather than on exact numerical values. This approach is more general than the classical AHP approach, since the real numbers can be represented as intervals with equal lower and upper bounds.

2.4.2 Specific problems related to the selection of a provider

Main objective here is to identify the problems that are commonly encountered by users in the selection of a provider. Although the literature has a lot to say about the fears and obstacles to outsourcing, it is generally silent about these problems. Some information in this regard is available on the websites of various logistics consultants and provider companies. According to some informal discussion with the logistics managers of some

companies that logistics managers have either outsourced their logistics activities or are planning to outsource. On that basis, the problems, which are specific to the selection of a provider, are:

i. A company, which is willing to outsource its logistics activities, may not have many persons 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.

ii. For the purpose of comparison, the users rarely have complete information about the prospective providers and they have to believe the information and/or assurances given by the prospective providers, which may not always be true.

iii. In comparing the prospective providers, the responses to request for proposal (RFP) are not directly comparable as many providers suggest many different solutions.

iv. Expectations of the user and the promises made by the providers are often unrealistic. Some users are not really in a position to define their actual logistics requirements.

v. For the comparison of prospective providers, there are many subjective criteria such as reputation, employee satisfaction levels, etc., which are difficult to compare. Further, how to compare various providers on many criteria of varying importance is again a problem. Some criteria may be more important than others.

vi. After considering all the relevant points, the selection process may run over months (Andersson & Norman 2002).

2.4.3 Criteria for the selection of a provider

This section is mainly aimed at identifying the criteria that need to be considered in logistics outsourcing.

The relevant criteria for the selection of a provider, which have been widely discussed in the literature, are compiled and presented in Table 2.3. These criteria form the basis for the development of a fuzzy AHP model.

Table 2.3: Summary of literature on the criteria for the selection of a provider

S.no.	Selection Criteria	Relevance in logistics outsourcing	References
1.	**Compatibility with the users (CPT)**	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.	Andersson and Norman (2002), Lynch (2000), Thompson (1996), Boyson *et al.* (1999), Mohanty and Deshmukh (1993)
2.	**Cost of service (CST)**	It refers to the total cost of logistics outsourcing, which should be minimum.	Lynch (2000), Langley *et al.* (1999), Boyson *et al.* (1999), Stock *et al.* (1998), Tam and Tummala (2001)
3.	**Quality of service (QLT)**	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.	Razzaque and Sheng (1998), Thompson (1996), Langley *et al.* (1999), Stock *et al.* (1998)
4.	**Reputation of the company (RPT)**	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.	Lynch (2000), Thompson (1996), Boyson *et al.* (1999)
5.	**Long-term relationships (LTR)**	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.	Lynch (2000), Boyson *et al.* (1999), Maltz (1995), Stank and Daugherty (1997)

S.no.	Selection Criteria	Relevance in logistics outsourcing	References
6.	**Performance measurement (PM)**	Provision of periodic evaluation of the performance of the provider enables the teo 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.	Bhatnagar *et al.* (1999), Lynch (2000), Langley *et al.* (1999)
7.	**Willingness to the use logistics manpower (WIL)**	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.	Razzaque and Sheng (1998), Ackerman (1996)
8.	**Flexibility in billing and payment (FBP)**	Flexibility in billing and payment conditions increases goodwill between the user and the provider.	Bradley (1994)
9.	**Quality of management (QM)**	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.	Andersson and Norman (2002), Lynch (2000), Boyson *et al.* (1999)
10.	**Information sharing and mutual trust (INF)**	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.	Lynch (2000), Stock (1990), Bagchi and Virum (1998)
11.	**Operational performance (OP)**	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.	Langley *et al.* (1999), Tam and Tummala (2001)

S.no.	Selection Criteria	Relevance in logistics outsourcing	References
12.	**Information technology (IT) 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.	Andersson and Norman (2002), Lynch (2000), Langley *et al.* (1999), Boyson *et al.* (1999), Langley *et al.* (2002), Rabinovich *et al.* (1999)
13.	**Size and quality of fixed assets (FA)**	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.	Boyson *et al.* (1999), Hum (2000)
14.	**Experience in similar products (ESP)**	Prior experience of the provider in the product line of user is the added advantage to the user.	Razzaque and Sheng (1998), Ackerman (1996), Richardson (1993)
15.	**Delivery performance (DP)**	Two dimension of DP, namely "speed" and "reliability", are important for the satisfaction of the user.	Stock *et al.* (1998), Gattorna and Walters (1996)
16.	**Employee satisfaction level (ESL)**	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.	Lynch (2000), Boyson *et al.* (1999), Langley *et al.* (2002)
17.	**Financial performance (FP)**	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.	Andersson and Norman (2002), Boyson *et al.* (1999), Gattorna and Walters (1996)
18.	**Market share (MS)**	The market share of the provider reflects its financial performance, customer satisfaction, and reputation.	Thompson (1996)

S.no.	Selection Criteria	Relevance in logistics outsourcing	References
19.	**Geographical spread (GS) and range of services provided (RS)**	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.	Boyson *et al.* (1999), Maltz (1995), Bradley (1994)
20.	**Risk management (RM)**	It is the capability of the provider to address any unforeseen problem. It is needed to ensure the continuity of the services.	Boyson *et al.* (1999)
21.	**Surge capacity of provider (SC)**	It becomes important if (due to sudden rise in demand of product) there is a rise in the logistics needs of the user.	Anonymous (1999).
22.	**Clause for arbitration and escape (CAR)**	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.	Richardson (1993)
23.	**Flexibility in operations and delivery (FOD)**	Flexibility in operations and delivery may enable the user to give customized service to its customers, particularly in special or nonroutine requests.	Stank and Daugherty (1997)
24.	**Cost of relationship (COR)**	The cost to form a satisfactory buyer - supplier relationships, including financial cost, human resources, and coordinating and controlling costs.	
25.	**Freight Price (FRP)**	The transportation cost, inventory cost, handling and package cost, damages during transportation, and insurance costs	
26.	**Financial Stability (FS)**	Supplier's probable unsafe financial conditions (such as liquidity) and financial instability (e.g., whether the supplier involves in other risky businesses)	

3. DATA and METHODOLOGY

3.1 Methodology

3.1.1 Analytical Hierarchy Process

The analytic hierarchy process (AHP) was first introduced by Saaty in 1971 to solve the scarce resources allocation and planning needs for the military (Saaty 1980). Since its introduction, the AHP has become one of the most widely used multiple-criteria decision-making (MCDM) methods, and has been used to solve unstructured problems in different areas of human needs and interests, such as political, economic, social and management sciences.

The AHP is based on the innate human ability to make sound judgments about small problems. It facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision. The AHP is implemented in the software of Expert Choice and it has been applied in a variety of decisions and planning projects in nearly 20 countries (Saaty 2001).

In AHP a problem is structured as a hierarchy. Once the hierarchy has been constructed, the decision-maker begins the prioritization procedure to determine the relative importance of the elements in each level. Prioritization involves eliciting judgments in response to questions about the dominance of one element over another with respect to a property. The scale used for comparisons in AHP enables the decision-maker to incorporate experience and knowledge intuitively and indicate how many times an element dominates another with respect to the criterion (Millet 1997). The decision-maker can express his preference between each pair of elements verbally as equally important, moderately more important, strongly more important, very strongly more important, and extremely more important. These descriptive preferences would then be translated into numerical values 1,3,5,7,9 respectively with 2,4,6, and 8 as intermediate values for comparisons between two successive qualitative judgments. Reciprocals of

these values are used for the corresponding transposed judgments. The table below shows the comparison scale used by AHP.

Table 3.1: The fundamental scale

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgment slightly favor one activity over another
5	Strong Importance	Experience and judgment strongly favor one activity over another
7	Very Strong Importance	An activity is favored very strongly over another; its dominance demonstrated in practice.
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it.

Finally, all the comparisons are synthesized to rank the alternatives. The output of AHP is a prioritized ranking of the decision alternatives based on the overall preferences expressed by the decision maker. Sensitivity analysis is used to investigate the impact of changing the priorities of the criteria on the final outcome.

i. The procedures of the AHP involve six essential steps (Cheng 1999; Chi & Kuo 2001; Kang & Lee 2006; Lee, Kang & Wang 2006; Murtaza 2003; Zahedi 1986):

ii. Define the unstructured problem and state clearly the objectives and outcomes.

iii. Decompose the complex problem into a hierarchical structure with decision elements (criteria, detailed criteria and alternatives).

iv. Employ pair-wise comparisons among decision elements and form comparison matrices.

v. Use the eigen value method to estimate the relative weights of the decision elements.

vi. Check the consistency property of matrices to ensure that the judgments of decision makers are consistent.

vii. Aggregate the relative weights of decision elements to obtain an overall rating for the alternatives.

3.1.2 Fuzzy Set Theory

In 1965, Lotfi A. Zadeh proposed a new approach to a rigorous, precise theory of approximation and vagueness based on generalization of standard set theory to fuzzy sets. Fuzzy sets and fuzzy logic are powerful mathematical tools for modeling: uncertain systems in industry, nature and humanity; and facilitators for common-sense reasoning in decision making in the absence of complete and precise information. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution (Bojadziev & Bojadziev 1998).

The classical set theory is built on the fundamental concept of set of which is either a member or not a member. A sharp, crisp and unambiguous distinction exists between a member and non-member for any well-defined set of entities in this theory and there is a very precise and clear boundary to indicate if an entity belongs to the set. But many real-world applications cannot be described and handled by classical set theory (Chen & Pham 2001). A fuzzy set is an extension of a crisp set. Crisp sets only allow full membership or non-membership at all, whereas fuzzy sets allow partial membership. In other words, an element may partially belong to a fuzzy set. Zadeh, proposed to use values ranging from 0 to 1 for showing the membership of the objects in a fuzzy set. Complete non-membership is represented by 0, and complete membership as 1. Values between 0 and 1 represent intermediate degrees of membership.

3.1.3 Fuzzy Numbers

Fuzzy numbers are the special classes of fuzzy quantities. A fuzzy number is a fuzzy quantity M that represents a generalization of a real number r. Intuitively, $M(x)$ should be a measure of how well $M(x)$ "approximates" r (Nguyen & Walker 2000). A fuzzy number M is a convex normalized fuzzy set. A fuzzy number is

characterized by a given interval of real numbers, each with a grade of membership between 0 and 1 (Deng 1999). A triangular fuzzy number (TFN), M is shown in Figure 3.1.

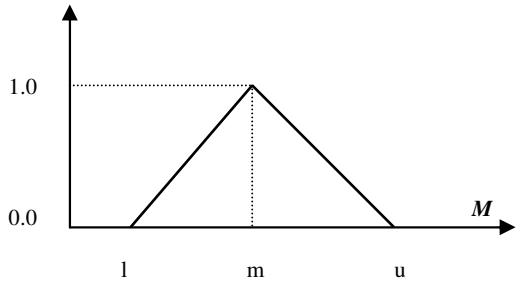

Figure 3.1: A triangular fuzzy number, $\tilde{M}$

Triangular fuzzy numbers (Table 3.2) are defined by three real numbers, expressed as *(l,m,u)*. The parameters *l, m,* and *u,* respectively, indicate the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. Their membership functions are described as;

$$\mu(x/\tilde{M}) = \begin{cases} 0, & x < l, \\ (x-l)/(m-l), & l \le x \le m, \\ (u-x)/(u-m), & m \le x \le u, \\ 0, & x > u \end{cases} \tag{3.1}$$

Table 3.2: Triangular fuzzy numbers

Linguistic variables	**Positive triangular fuzzy numbers**	**Positive reciprocal triangular fuzzy numbers**
Just Equal	(1, 1, 1)	(1, 1, 1)
Equally Important	(1/2, 1, 3/2)	(2/3, 1, 2)
Weakly More Important	(1, 3/2, 2)	(1/2, 2/3, 1)
Strongly More Important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Very Strongly More Important	(2, 5/2, 3)	(1/3, 2/5, 1/2)
Absolutely More Important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)

In applications it is convenient to work with TFNs because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. In this study TFNs in the FAHP is adopted.

3.1.4 Algebraic Operations on TFNs

Although we are familiar with algebraic operations with crisp numbers, when we want to use fuzzy sets in applications, we have to deal with fuzzy numbers. We can define various operations on TFNs. But in this section, three important operations used in this study are illustrated (Tang & Beynon 2005). If we define, two TFNs A and B by the triplets $A = (l_1, m_1, u_1)$ and $B = (l_2, m_2, u_2)$. Then

Addition:

$$A + B = (l_1, m_1, u_1) + (l_2, m_2, u_2) \tag{3.2}$$
$$= (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

Multiplication:

$$A.B = (l_1, m_1, u_1).(l_2, m_2, u_2) \tag{3.3}$$
$$= (l_1.l_2, m_1.m_2, u_1.u_2)$$

Inverse:

$$(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1) \tag{3.4}$$

3.1.5 Fuzzy Analytical Hierarchy Process (FAHP)

The Analytic Hierarchy Process (AHP) has been widely used to solve multiple-criteria decision-making problems. However, due to vagueness and uncertainty in the decision-maker's judgment, a crisp, pair-wise comparison with a conventional AHP may be unable to accurately capture the decision-maker's judgment (Ayağ 2005). In conventional AHP, the pair-wise comparison is established using a nine-point scale which converts the human preferences between available alternatives as equally, moderately, strongly, very strongly or extremely preferred. Even though the discrete scale of AHP has the advantages of simplicity and ease of use, it is not sufficient to take

into account the uncertainty associated with the mapping of one's perception to a number. Therefore, fuzzy logic is introduced into the pair-wise comparison to deal with the deficiency in the traditional AHP. This is referred to as fuzzy AHP.

The linguistic assessment of human feelings and judgments are vague and it is not reasonable to represent it in terms of precise numbers. To give interval judgments than fixed value judgments is more confident for decision makers. So, triangular fuzzy numbers are used to decide the priority of one decision variable over other in fuzzy AHP (Chan & Kumar 2005). Fuzzy AHP is an efficient tool to handle the fuzziness of the data involved in deciding the preferences of different decision variables. The comparisons produced by the expert are represented in the form of triangular fuzzy numbers to construct fuzzy pair-wise comparison matrices (Ghodsypour & O'Brien 1998). By the help of FAHP, we can efficiently handle the fuzziness of the data involved in the decision of selecting best supplier. It is easier to understand and it can effectively handle both qualitative and quantitative data in the multi-attribute decision making problems. In this approach triangular fuzzy numbers are used for the preferences of one criterion over another and then by using the extent analysis method, the synthetic extent value of the pair-wise comparison is calculated. Based on this approach, the weight vectors are decided and normalized, thus the normalized weight vectors will be determined. As a result, based on the different weights of criteria and attributes the final priority weights of the alternative suppliers are decided. The highest priority would be given to the supplier with highest weight (Chan & Kumar 2005).

3.1.6 Algorithm of FAHP Method

In this study the extent FAHP is utilized, which was originally introduced by Chang (1996). Let $X = \{x_1, x_2, x_3, ..., x_n\}$ an object set, and $G = \{g_1, g_2, g_3, ..., g_n\}$ be a goal set. According to the method of Chang's extent analysis, each object is taken and extent analysis for each goal performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following signs:

$$M^1{}_{gi}, M^2{}_{gi}, ...M^m{}_{gi,} \qquad i = 1,2,....,n,$$

where M^{j}_{gi} ($j = 1, 2, ...,m$) all are TFNs. The steps of Chang's extent analysis can be given as in the following:

Step 1: The value of fuzzy synthetic extent with respect to the i th object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1} \tag{3.5}$$

To obtain $\sum_{j=1}^{m} M^{j}_{gi}$, perform the fuzzy addition operation of m extent analysis values for a particular matrix such that:

$$\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{3.6}$$

and to obtain $\left[\sum_{j=1}^{n} \sum_{j=1}^{m} M^{j}_{gi} \right]^{-1}$, perform the fuzzy addition operation of M^{j}_{gi} (j = 1, 2, ...,m) values such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{3.7}$$

and then compute the inverse of the vector above, such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M^{j}_{gi} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \quad . \tag{3.8}$$

Step 2: As $\tilde{M}_1 = (l_1, m_1, u_1)$ and $\tilde{M}_2 = (l_2, m_2, u_2)$ are two triangular fuzzy numbers, the degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ defined as:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = \sup_{y \geq x} \left[\min\left(\mu_{\tilde{M}_1}(x), \mu_{\tilde{M}_2}(y) \right) \right] \tag{3.9}$$

and can be equivalently expressed as follows:

$$V\left(\tilde{M}_2 \geq \tilde{M}_1\right) = hgt(\tilde{M}_1 \cap \tilde{M}_2) = \mu_{M_2}(d) \tag{3.10}$$

$$= \begin{cases} 1, & if \quad m_2 \geq m_1 \\ 0, & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \tag{3.11}$$

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy M_i (i=1, 2, k) numbers can be defined by

$$V(M \geq M_1, M_2, ...M_k) = V\left[(M \geq M_1) \ \ and \ \ (M \geq M_2) \ \ and....and \ \ (M \geq M_k)\right]$$

$$= \min \ \ V(M \geq M_i), \ \ i = 1,2,3,...., k \tag{3.12}$$

Assume that $d\left(A_i\right) = \min V(S_i \geq S_k)$

for $k = 1,2,....,n; k \neq i$. Then the weight vector is given by

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \tag{3.13}$$

where $A_i = (i = 1,2,...n)$ are n elements.

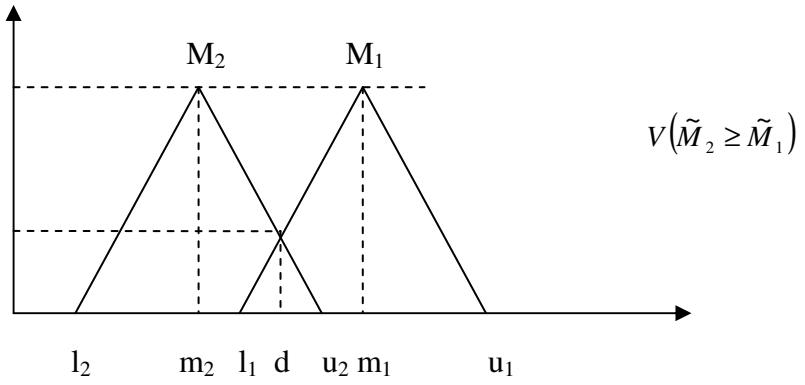

Figure 3.2: The intersection between M_1 and M_2
Source: Kahraman *et al.* 2004.

Figure 3.2 illustrates Eq. (11) where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} to compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$.

Step 4: Via normalization, the normalized weight vectors are

$$W = (d(A_1), d(A_2), ..., d(A_n))^T \tag{3.14}$$

where W is a non-fuzzy number.

3.1.7 Applications of Fuzzy AHP methodology in literature

There are many fuzzy AHP methods proposed by various authors. These methods are systematic approaches to the alternative selection and justification problem by using the concepts of fuzzy set theory and hierarchical structure analysis. Decision makers usually find that it is more confident to give interval judgments than fixed value judgments. This is because usually he/she is unable to explicit about his/her preferences due to the fuzzy nature of the comparison process.

The earliest work in fuzzy AHP appeared in van Laarhoven and Pedrycz (1983), which compared fuzzy ratios described by triangular membership functions. Buckley (1985) determines fuzzy priorities of comparison ratios whose membership functions trapezoidal. Stam *et al.* (1996) explore how recently developed artificial intelligence techniques can be used to determine or approximate the preference ratings in AHP. They conclude that the feed-forward neural network formulation appears to be a powerful tool for analyzing discrete alternative multi-criteria decision problems with imprecise or fuzzy ratio-scale preference judgments. Chang (1996) introduces a new approach for handling fuzzy AHP, with the use of triangular fuzzy numbers for pair-wise comparison scale of fuzzy AHP, and the use of the extent analysis method for the synthetic extent values of the pair-wise comparisons. Ching-Hsue (1997) proposes a new algorithm for evaluating naval tactical missile systems by the fuzzy analytical hierarchy process based on grade value of membership function. Weck *et al.* (1997) present a method to evaluate different production cycle alternatives adding the mathematics of fuzzy logic to the classical AHP. Any production cycle evaluated in this

manner yields a fuzzy set. The outcome of the analysis can finally be defuzzified by forming the surface center of gravity of any fuzzy set, and the alternative production cycles investigated can be ranked in order in terms of the main objective set. Kahraman *et al.* (1998) use a fuzzy objective and subjective method obtaining the weights from AHP and make a fuzzy weighted evaluation. Deng (1999) presents a fuzzy approach for tackling qualitative multi-criteria analysis problems in a simple and straightforward manner. Lee *et al.* (1999) review the basic ideas behind the AHP. Based on these ideas, they introduce the concept of comparison interval and propose a methodology based on stochastic optimization to achieve global consistency and to accommodate the fuzzy nature of the comparison process. Cheng *et al.* (1999) propose a new method for evaluating weapon systems by analytical hierarchy process based on linguistic variable weight. Zhu *et al.* (1999) make a discussion on extent analysis method and applications of fuzzy AHP. Chan *et al.* (2000a) present a technology selection algorithm to quantify both tangible and intangible benefits in fuzzy environment. They describe an application of the theory of fuzzy sets to hierarchical structural analysis and economic evaluations. By aggregating the hierarchy, the preferential weight of each alternative technology is found, which is called fuzzy appropriate index. The fuzzy appropriate indices of different technologies are then ranked and preferential ranking orders of technologies are found. From the economic evaluation perspective, a fuzzy cash flow analysis is employed. Chan *et al.* (2000b) report an integrated approach for the automatic design of FMS, which uses simulation and multi-criteria decision making techniques. The design process consists of the construction and testing of alternative designs using simulation methods. The selection of the most suitable design (based on AHP) is employed to analyze the output from the FMS simulation models. Intelligent tools (such as expert systems, fuzzy systems and neural networks) are developed for supporting the FMS design process. Active X technique is used for the actual integration of the FMS automatic design process and the intelligent decision support process. Leung and Cao (2000) propose a fuzzy consistency definition with consideration of a tolerance deviation. Essentially, the fuzzy ratios of relative importance, allowing certain tolerance deviation, are formulated as constraints on the membership values of the local priorities. The fuzzy local and global weights are determined via the extension principle. The alternatives are ranked on the basis of the global weights by application of maximum –

minimum set ranking method. Kuo *et al.* (2002) develop a decision support system for locating a new convenience store. The first component of the proposed system is the hierarchical structure development of fuzzy analytic process.

Enea and Piazza (2004), focused on the constraints that have to be considered within fuzzy AHP. They used constrained fuzzy AHP in project selection. Kahraman *et al.* (2004) used the fuzzy AHP for comparing catering firms in Turkey. The means of the triangular fuzzy numbers produced by the customers and experts for each comparison were successfully used in the pair-wise comparison matrices. Tang and Beynon (2005) used fuzzy AHP method for the application and development of a capital investment study. They tried to select the type of fleet car to be adopted by a car rental company. Tolga *et al.* (2005) used fuzzy replacement analysis and analytic hierarchy process in the selection of operating system. The economic part of the decision process had been developed by Fuzzy Replacement Analysis. Non-economic factors and financial figures had been combined by using a fuzzy AHP approach. Başlıgil (2005) provided an analytical tool to select the best software providing the most customer satisfaction. Chan and Kumar (2005) proposed a model for providing a framework for an organization to select the global supplier by considering risk factors. They used fuzzy extended analytic hierarchy process in the selection of global supplier in the current business scenario.

While Ngai and Chan (2005) present a conventional AHP application to select the most appropriate tool to support knowledge management (KM), Wang and Chang (2006) construct an analytic hierarchy prediction model based on the consistent fuzzy preference relations to identify the essential success factors for an organization in KM implementation, KM project forecast, and identification of necessary actions before initiating KM. Bozbura, Beskese, and Kahraman (2006) propose a FAHP methodology to improve the quality of prioritization of human capital measurement indicators under fuzziness. Tzeng, Chiang, and Li (2006) design a generalized quantitative evaluation model, which considers the inter-affected relation between criteria and the fuzziness of subjective perception concurrently, to evaluate the effectiveness of e-learning. Factor analysis is applied to address the independent relations of evaluation criteria, and decision-making trial and evaluation laboratory (DEMATEL) method is used to deal

with dependent relations of criteria. The AHP and the fuzzy integral methods are then used to obtain the final effectiveness of the e-learning programs.

3.2 Application of FAHP methodology

3.2.1 A Case Company

The application of the fuzzy AHP approach has been demonstrated for a medium-sized and growth-oriented fast-moving-consumer-goods (FMCG) company, which is steadily moving towards IT enablement of its supply chain. It has partially outsourced its outbound logistics to carrying and forwarding agents. The company is willing to outsource its entire logistics activities.

The opinion of the logistics manager of the company was sought in the formation of pair-wise comparison matrices.

3.2.2 Structuring Selection Model

The goal is to choose the best logistics service provider for a case company. So, this goal is placed at the top of the hierarchy. The hierarchy descends from the more general criteria in the second level to sub-criteria in the third level to the alternatives at the bottom or fourth level. General criteria level involved five major criteria: Cost of service, operational performance, financial performance, reputation of the 3PL, and long-term relationships. Each of these in turn needed further decomposition into specific items in the third level. For example, cost of service decomposed into three criteria: freight price, terms of payment and extra costs. Also, financial performance includes three sub-criteria in the third level of hierarchy: flexibility in billing and payment, financial stability, range of services provided. Similarly, quality, IT capability, size and quality of fixed assets, delivery performance, employee satisfaction level, flexibility in operations and delivery are located under operational performance in the third level of the hierarchy. The four sub-criteria were included for reputation of the 3PL in the third level. These are market share, geographic spread and access to retailers, market knowledge and experience in similar products. The last main criterion, long-term relationships, includes six sub-criteria. These are information sharing, willingness to use logistics manpower, risk management, quality of management, compatibility and

cost of relationships. Three logistics service providers are considered for the decision alternatives, and located them on the bottom level of the hierarchy. These are Alternative A, B, and C. Figure 3.3 shows a hierarchical representation of the selecting best logistics service provider decision-making model.

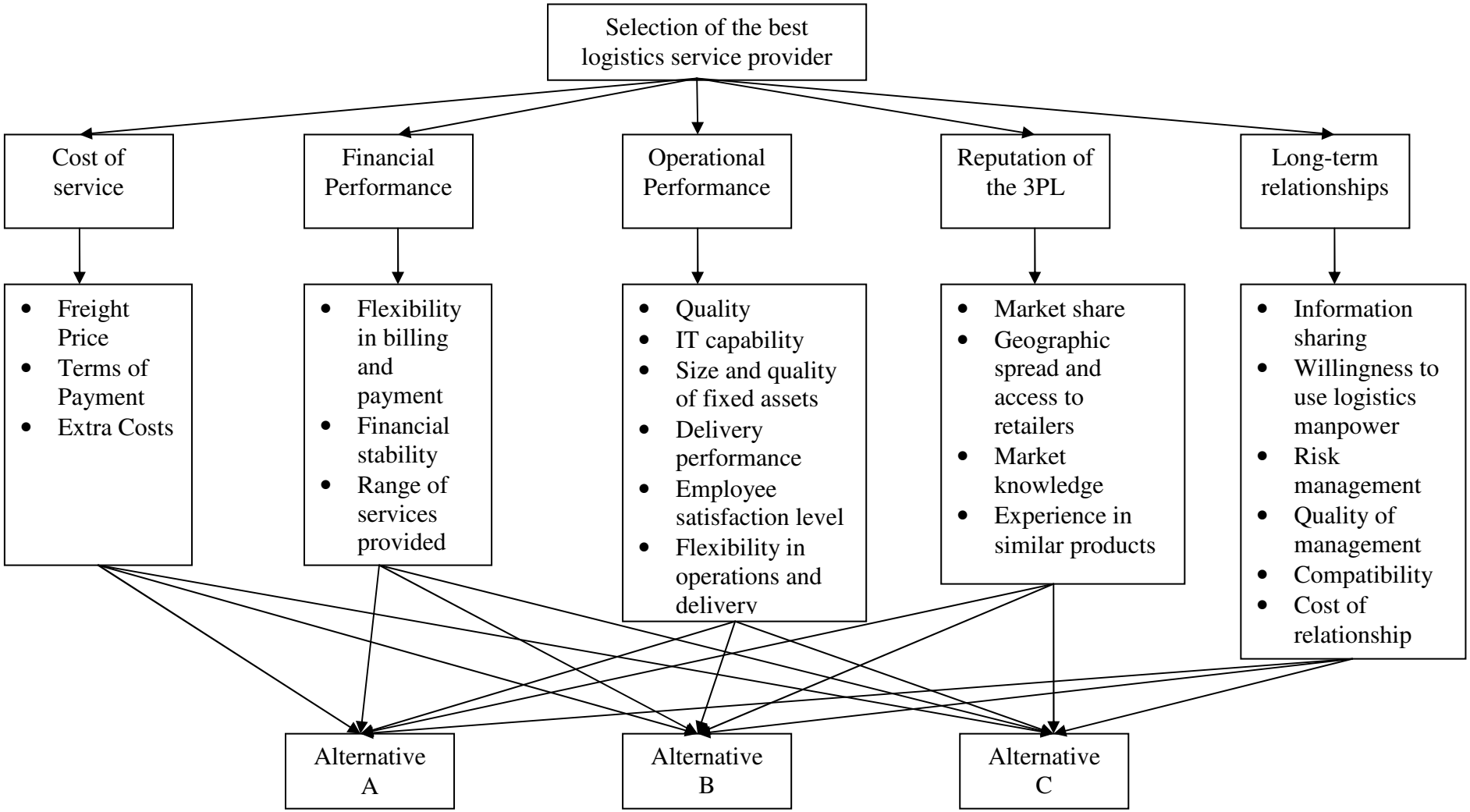

Figure 3.3: Decision Hierarchy

3.2.3 Potential Providers

Three providers, namely A, B, and C, will be compared. Of these three providers, A is asset-based and has its own means of transportation, distribution, and warehousing. B is similar to a 4PL company with advanced IT, supply chain, and change management capabilities. However, the provider C is a non-asset-based company and, instead of having its own physical assets, it relies on contracting the logistics assets as per the requirement of the users.

In Table 3.3, qualifications of potential providers can be seen. For each of sub-criteria, potential providers (alternative A, B, and C) have a level such as very low, low, normal, high, and very high. This classification of alternatives according to their capabilities, helps making pair-wise comparison matrices, afterwards.

Table 3.3: Qualifications of potential providers

Main Criteria	Sub-Criteria	Alternative A	Alternative B	Alternative C
Cost of Service	Freight Price	Low	Normal	High
	Terms of Payment	Very Low	High	Normal
	Extra Costs	High	Normal	Low
Financial Performance	Flexibility in billing and payment	Low	Normal	High
	Financial stability	Normal	High	High
	Range of services provided	Low	High	Very High
Operational Performance	Quality	Normal	High	High
	IT capability	Normal	Very High	High
	Size and quality of fixed assets	High	Normal	Low
	Delivery performance	Low	High	Normal
	Employee satisfaction level	Low	High	Normal
	Flexibility in operations and delivery	Low	Very High	High
Reputation of the 3PL	Market share	Normal	High	Low
	Geographic spread and access to retailers	Normal	High	Normal

Main Criteria	Sub-Criteria	Alternative A	Alternative B	Alternative C
	Market knowledge	High	High	Normal
	Experience in similar products	Normal	Normal	Very High
Long-term Relationships	Information sharing	High	Normal	High
	Willingness to use logistics manpower	Normal	Normal	High
	Risk management	Low	Normal	High
	Quality of management	Low	Normal	High
	Compatibility	Low	High	High
	Cost of relationship	Very High	Normal	High

3.2.4 Pair wise comparisons matrices

After constructing the selection model hierarchy, pair-wise comparisons must be performed systematically to include all the combinations of criteria/sub-criteria/secondary sub-criteria/alternatives relationships. The criteria and sub-criteria are compared according to their relative importance with respect to the parent element in the adjacent upper level. It is hoped that we would be able to go through pair-wise comparisons together with the decision makers. It was not possible due to the differences among the schedule of the managers. Hence, questionnaires including all possible pair-wise comparison combinations must be prepared and send to the decision makers.

3.2.4.1 Questionnaire Design and Data Collection

51 questions questionnaires (see Appendix A.2) including all possible pair-wise comparison combinations were distributed to the decision makers. Decision makers made all the pair wise comparisons using semantic terms from the fundamental scale. Then, fundamental scale is translated to the corresponding numbers, separately. The questions to ask when comparing two criteria being compared, which is considered more important by the decision-maker selecting the best supplier, and how much more important is it with respect to selection of the best supplier. Questionnaire (see Appendix A.2) has been sent to nearly 40 people including academic people,

professional experts, students and colleagues and has been replied approximately 50 percent.

3.2.4.2 Integration the Opinions of Decision Makers

After performing all pair-wise comparisons by the decision-makers, individual judgments are aggregated using the geometric mean as Saaty suggested (Saaty 1990). In the formation of a pair-wise comparison matrix, group decision-making may be used to avoid the biased attitude of the decision-maker towards a particular provider. Dyer and Forman (1992) have suggested several ways for including the views and judgments of group members in the pair wise comparison of matrices. These are (i) consensus, (ii) vote or compromise, (iii) geometric mean of the individual's judgments, and (iv) a separate model.

Suppose two people compare two apples and provide the judgments for the larger over the smaller, 4 and 3 respectively. So the judgments about the smaller relative to the larger are 1/4 and 1/3.

Arithmetic mean

$4 + 3 = 7 \quad 7/2 = 3.5$

$1/3.5 \neq 1/4 + 1/3 = 7/12$

Geometric mean

$\sqrt{4 \times 3} = 3.46$

$\frac{1}{\sqrt{4 \times 3}} = \sqrt{\frac{1}{4} \times \frac{1}{3}} = \frac{1}{3{,}46}$

That the geometric mean is the unique way to combine group judgments is a theorem in mathematics.

The judgments were based upon the gathered information through the questionnaires. The results are then combined by applying the geometric mean.

Geometric average is applied to combine the fuzzy weights of decision makers

$$\overline{\tilde{W}_i} = \left(\prod_{k=1}^{K} \tilde{W}_i^k \right)^{\frac{1}{K}}, \quad \forall k = 1, 2, \ldots, K \tag{3.15}$$

where

$\overline{\tilde{W}_i}$: combined fuzzy weight of decision element i of K decision makers.

$\tilde{W}_i^k$: fuzzy weight of decision element i of decision maker k.

K : number of decision makers.

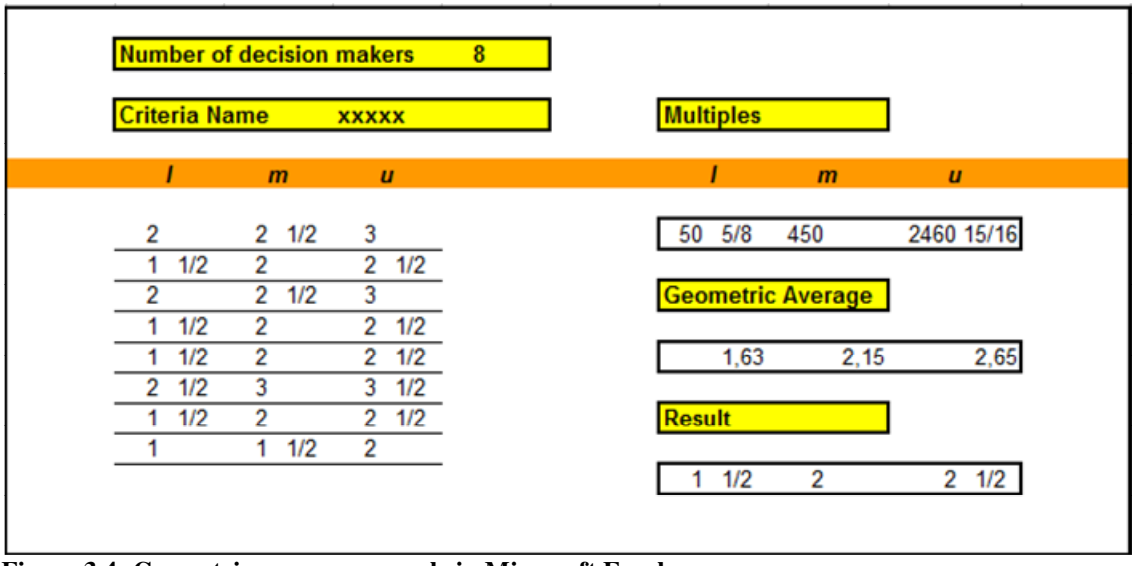

Figure 3.4: Geometric average example in Microsoft Excel

3.2.5 Data Input and Analysis using Fuzzy AHP

3.2.5.1 The Fuzzy Evaluation Matrix with Respect to Goal

To build the pair – wise comparison matrixes for the main and sub-attributes, a questionnaire (see Appendix A.2) is sent to some academics and professionals. The results are calculated by taking the geometric mean of individual evaluations. For the first step of the analysis, the pair-wise comparison matrix for the main attributes is built (see Table 3.4).

Table 3.4: Pair – wise comparison matrix for main attributes

	CST	FP	OP	RPT	LTR
CST	(1, 1, 1)	(1/2, 1, 3/2)	(1, 1, 1)	(1, 3/2, 2)	(1/2, 1, 3/2)
FP	(2/3, 1, 2)	(1, 1, 1)	(2/3, 1, 2)	(1, 3/2, 2)	(1, 3/2, 2)
OP	(1, 1, 1)	(1/2, 1, 3/2)	(1, 1, 1)	(3/2, 2, 5/2)	(3/2, 2, 5/2)
RPT	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)	(1/2, 1, 3/2)
LTR	(2/3, 1, 2)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(2/3, 1, 2)	(1, 1, 1)

For the first level (*i.e.* for main attributes), from Table 3.4, according to extent analysis, fuzzy synthesis values respect to main attributes are calculated like in equation (3.6):

$$S_{CST} = (4.00, 5.50, 7.00) \otimes (1/36.33, 1/26.50, 1/19.97) = (0.11, 0.21, 0.35)$$

$$S_{FP} = (4.33, 6.00, 9.00) \otimes (1/36.33, 1/26.50, 1/19.97) = (0.12, 0.23, 0.45)$$

$$S_{OP} = (5.50, 7.00, 8.50) \otimes (1/36.33, 1/26.50, 1/19.97) = (0.15, 0.26, 0.43)$$

$$S_{RPT} = (2.90, 3.83, 5.17) \otimes (1/36.33, 1/26.50, 1/19.97) = (0.08, 0.14, 0.26)$$

$$S_{LTR} = (3.23, 4.17, 6.67) \otimes (1/36.33, 1/26.50, 1/19.97) = (0.09, 0.16, 0.33)$$

These fuzzy values are compared by using equation (3.11) and

$$V(S_{CST} \geq S_{FP}) = 0.92,\ V(S_{CST} \geq S_{OP}) = 0.78,\ V(S_{CST} \geq S_{RPT}) = 1,\ V(S_{CST} \geq S_{LTR}) = 1$$

$$V(S_{FP} \geq S_{CST}) = 1,\ V(S_{FP} \geq S_{OP}) = 0.89,\ V(S_{FP} \geq S_{RPT}) = 1,\ V(S_{FP} \geq S_{LTR}) = 1$$

$$V(S_{OP} \geq S_{CST}) = 1,\ V(S_{OP} \geq S_{FP}) = 1,\ V(S_{OP} \geq S_{RPT}) = 1,\ V(S_{OP} \geq S_{LTR}) = 1$$

$$V(S_{RPT} \geq S_{CST}) = 0.70,\ V(S_{RPT} \geq S_{FP}) = 0.63,\ V(S_{RPT} \geq S_{OP}) = 0.47,\ V(S_{RPT} \geq S_{LTR}) = 0.93$$

$$V(S_{LTR} \geq S_{CST}) = 0.82,\ V(S_{LTR} \geq S_{FP}) = 0.76,\ V(S_{LTr} \geq S_{OP}) = 0.63,\ V(S_{LTR} \geq S_{RPT}) = 1$$

are obtained.

Then priority (importance) weights are calculated by using equation (3.12):

$$d'(CST) = \min(0.92,\ 0.78,\ 1,\ 1) = 0.78,$$

$$d'(FP) = \min(1,\ 0.89,\ 1,\ 1) = 0.89,$$

$d'(OP) = \min(1,\ 1,\ 1,\ 1) = 1.00$,

$d'(RPT) = \min(0.70,\ 0.63,\ 0.47,\ 0.93) = 0.47$,

$d'(LTR) = \min(0.82,\ 0.76,\ 0.63,\ 1) = 0.63$

For each pair-wise comparison, the minimum of the degrees of possibility is found as above. These values form $W' = (0.78,\ 0.89,\ 1,\ 0{,}47\ \ 0.63)^T$ vector. Via normalization, the priority weights (*i.e.* eigen values) of the main attributes respect to main goal are calculated as $(0.21,\ \ 0.24,\ \ 0.27,\ \ 0.12,\ \ 0.16)$.

According to this result firms give importance to operational performance, financial performance, cost of service, long-term relationship and reputation respectively in selecting the best logistics service provider.

Table 3.5: Summary of priority weights of main criteria with respect to goal

	Main attributes of the Goal				
	Cost of Service	**Financial Performance**	**Operational Performance**	**Reputation of the 3PL**	**Long-term relationships**
Weight	0.21	0.24	0.27	0.12	0.16

These calculation processes are really hard and difficult, if they are made manually. So, a program is developed via Microsoft Excel. Hence, whole process can be calculated automatically. When a pair wise comparison matrix is entered to program, each of steps of fuzzy AHP algorithm is calculated by the program and the result is given.

For example, in Figure 3.5, pair wise comparison matrix for main attributes was entered like in Table 3.4. After that, the program calculates synthesis values respect to main goal equal like in equation (3.6) and gives equal result with manual calculation.

In Figure 3.6, these fuzzy values are compared by using equation (3.11). Then, priority weights are calculated by using equation (3.12). Priority weights forms W' vector. After the normalization of these values priority weight respect to main goal is calculated as $(0.21,\ \ 0.24,\ \ 0.27,\ \ 0.12,\ \ 0.16)$. This result supports reliability of program. So, the fuzzy AHP excel program will be used for other pair wise comparison matrices.

	C1			C2			C3			C4			C5			C6		
C1	1	1	1	1/2	1	1 1/2	1	1	1	1	1 1/2	2	1/2	1	1 1/2			
C2	2/3	1	2	1	1	1	2/3	1	2	1	1 1/2	2	1	1 1/2	2			
C3	1	1	1	1/2	1	1 1/2	1	1	1	1 1/2	2	2 1/2	1 1/2	2	2 1/2			
C4	1/2	2/3	1	1/2	2/3	1	2/5	1/2	2/3	1	1	1	1/2	1	1 1/2			
C5	2/3	1	2	1/2	2/3	1	2/5	1/2	2/3	2/3	1	2	1	1	1			
C6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
C7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Pair wise comparison matrix

Kriter Sayısı	3

19.97	Tüm I. indislerin toplamı
26.50	Tüm II. indislerin toplamı
36.33	Tüm III. indislerin toplamı

l	*m*	*u*
4.00 C1 I.indis toplamı	5.50 C1 II.indis toplamı	7.00 C1 III.indis toplamı
4.33 C2 I.indis toplamı	6.00 C2 II.indis toplamı	9.00 C2 III.indis toplamı
5.50 C3 I.indis toplamı	7.00 C3 II.indis toplamı	8.50 C3 III.indis toplamı
2.90 C4 I.indis toplamı	3.83 C4 II.indis toplamı	5.17 C4 III.indis toplamı
3.23 C5 I.indis toplamı	4.17 C5 II.indis toplamı	6.67 C5 III.indis toplamı
1.00 C6 I.indis toplamı	1.00 C6 II.indis toplamı	1.00 C6 III.indis toplamı
1.00 C7 I.indis toplamı	1.00 C7 II.indis toplamı	1.00 C7 III.indis toplamı
1.00 C8 I.indis toplamı	1.00 C8 II.indis toplamı	1.00 C8 III.indis toplamı

									l	*m*	*u*
SC1	4.00	5.50	7.00	X	0.0275	0.0377	0.0501	=	0.11	0.21	0.35
SC2	4.33	6.00	9.00	X	0.0275	0.0377	0.0501	=	0.12	0.23	0.45
SC3	5.50	7.00	8.50	X	0.0275	0.0377	0.0501	=	0.15	0.26	0.43
SC4	2.90	3.83	5.17	X	0.0275	0.0377	0.0501	=	0.08	0.14	0.26
SC5	3.23	4.17	6.67	X	0.0275	0.0377	0.0501	=	0.09	0.16	0.33
SC6	1.00	1.00	1.00	X	0.0275	0.0377	0.0501	=	0.03	0.04	0.05
SC7	1.00	1.00	1.00	X	0.0275	0.0377	0.0501	=	0.03	0.04	0.05
SC8	1.00	1.00	1.00	X	0.0275	0.0377	0.0501	=	0.03	0.04	0.05

Synthesis values respect to main goal are calculated like in equation (3.6).

$$V(\tilde{M}_2 \geq \tilde{M}_1) = hgt(\tilde{M}_1 \cap \tilde{M}_2) = \mu_{M_2}(d)$$

$$= \begin{cases} 1, & if \quad m_2 \geq m_1 \\ 0, & if \quad l_1 \geq u_2 \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & othe \end{cases}$$

Figure 3.5: Fuzzy AHP Program Screen I

	$1, \ if \ \ m_2 \geq m_1$	$0, \ if \ \ l_1 \geq u_2$	$\frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, otherwise$	Sonuç
V (SC1 ≥ SC2)	Tanımsız	Tanımsız	0.924584	**0.92**
V (SC1 ≥ SC3)	Tanımsız	Tanımsız	0.778729	**0.78**
V (SC1 ≥ SC4)	1	Tanımsız	Tanımsız	**1.00**
V (SC1 ≥ SC5)	1	Tanımsız	Tanımsız	**1.00**
V (SC1 ≥ SC6)	1	Tanımsız	Tanımsız	**1.00**
V (SC1 ≥ SC7)	1	Tanımsız	Tanımsız	**1.00**
V (SC1 ≥ SC8)	1	Tanımsız	Tanımsız	**1.00**
V (SC2 ≥ SC1)	1	Tanımsız	Tanımsız	**1.00**
V (SC2 ≥ SC3)	Tanımsız	Tanımsız	0.888061	**0.89**
V (SC2 ≥ SC4)	1	Tanımsız	Tanımsız	**1.00**
V (SC2 ≥ SC5)	1	Tanımsız	Tanımsız	**1.00**
V (SC2 ≥ SC6)	1	Tanımsız	Tanımsız	**1.00**
V (SC2 ≥ SC7)	1	Tanımsız	Tanımsız	**1.00**
V (SC2 ≥ SC8)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC1)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC2)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC4)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC5)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC6)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC7)	1	Tanımsız	Tanımsız	**1.00**
V (SC3 ≥ SC8)	1	Tanımsız	Tanımsız	**1.00**
V (SC4 ≥ SC1)	Tanımsız	Tanımsız	0.702726	**0.70**
V (SC4 ≥ SC2)	Tanımsız	Tanımsız	0.630475	**0.63**
V (SC4 ≥ SC3)	Tanımsız	Tanımsız	0.473316	**0.47**
V (SC4 ≥ SC5)	Tanımsız	Tanımsız	0.93102	**0.93**
V (SC4 ≥ SC6)	1	Tanımsız	Tanımsız	**1.00**
V (SC4 ≥ SC7)	1	Tanımsız	Tanımsız	**1.00**
V (SC4 ≥ SC8)	1	Tanımsız	Tanımsız	**1.00**

Figure 3.6: Fuzzy AHP Program Screen II

Fuzzy values are compared by using equation (3.11).

	Min	Priority Weights	Normalization
d'(C1)	0.78	0.78	0.21

	Min	Priority Weights	Normalization
d'(C2)	0.89	0.89	0.24

	Min	Priority Weights	Normalization
d'(C3)	1.00	1	0.27

	Min	Priority Weights	Normalization
d'(C4)	0.47	0.47	0.13

Priority weights
W'
(0.78, 0.89, 1, 0.47, 0.63, 0, 0, 0)

Normalization of priority weight
W'
(0.21, 0.24, 0.27, 0.13, 0.17, 0.00

Priority weights are calculated by using equation (3.12).

Normalization of priority weight like in equation (3.14).

3.2.5.2 Evaluation of the sub-attributes with respect to "Cost of Service"

At the second level, the weights of the sub-attributes of each main attribute are calculated. As can be seen from Figure 3.3, Cost of Service (CST) has three sub-attributes; Freight Price (FRP), Terms of Payment (TOP), and Extra Costs (EXC). The pair-wise comparison for these three can be seen in Table 3.6.

Table 3.6: Pair – wise comparison matrix for the sub-attributes of "Cost of Service"

	FRP	TOP	EXC
FRP	(1, 1, 1)	(1, 3/2, 2)	(1, 3/2, 2)
TOP	(1/2, 2/3, 1)	(1, 1, 1)	(3/2, 2, 5/2)
EXC	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)

The values of fuzzy synthetic extents with respect to "Cost of Service" are found as in Table 3.7.

Table 3.7: Summary of priority weights for the sub attributes of the "Cost of Service"

Sub attributes of the "Cost of Service"			
	Freight Price	**Terms of Payment**	**Extra Costs**
Weight	0.45	0.41	0.14

3.2.5.3 Evaluation of the sub-attributes with respect to "Financial Performance"

The second main attribute in the model, Financial Performance (FP), has three sub-attributes; Flexibility in billing and payment (FBP), Financial stability (FS), and Range of services provided (RS). The pair-wise comparison for these three can be seen in Table 3.8.

Table 3.8: Pair – wise comparison matrix for the sub-attributes of "Financial Performance"

	FBP	FS	RS
FBP	(1, 1, 1)	(1, 1, 1)	(1/2, 1, 3/2)
FS	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
RS	(2/3, 1, 2)	(1, 1, 1)	(1, 1, 1)

The values of fuzzy synthetic extents with respect to "Financial Performance" are found as in Table 3.9.

Table 3.9: Summary of priority weights for the sub attributes of the "Financial Performance"

Sub attributes of the "Financial Performance"			
	Flexibility in Billing and Payment	**Financial Stability**	**Range of Services Provided**
Weight	0.33	0.34	0.33

3.2.5.4 Evaluation of the sub-attributes with respect to "Operational Performance"

The third main attribute in the model, Operational Performance (OP), has six sub-attributes; Quality (QLT), IT capability (IT), Size and quality of fixed assets (FA), Delivery performance (DP), Employee satisfaction level (ESL), and Flexibility in operations and delivery (FOD). The pair-wise comparison for these six can be seen in Table 3.10.

Table 3.10: Pair – wise comparison matrix for the sub-attributes of "Operational Performance"

	QLT	**IT**	**FA**	**DP**	**ESL**	**FOD**
QLT	(1, 1, 1)	(1, 1, 1)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1, 3/2, 2)
IT	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)	(1, 1, 1)	(1, 3/2, 2)	(1, 1, 1)
FA	(2/3, 1, 2)	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
DP	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)	(1, 1, 1)	(1, 3/2, 2)	(1/2, 1, 3/2)
ESL	(2/3, 1, 2)	(1/2, 2/3, 1)	(2/3, 1, 2)	(1/2, 2/3, 1)	(1, 1, 1)	(1, 3/2, 2)
FOD	(1/2, 2/3, 1)	(1, 1, 1)	(2/3, 1, 2)	(2/3, 1, 2)	(1/2, 2/3, 1)	(1, 1, 1)

The values of fuzzy synthetic extents with respect to "Operational Performance" are found as in Table 3.11.

Table 3.11: Summary of priority weights for the sub attributes of the "Operational Performance"

Sub attributes of the "Operational Performance"						
	Quality	**IT Capability**	**Size and Quality of Fixed Assets**	**Delivery Performance**	**Employee Satisfaction Level**	**Flexibility in Operations and Delivery**
Weight	0.17	0.19	0.16	0.17	0.16	0.15

3.2.5.5 Evaluation of the sub-attributes with respect to "Reputation of the 3PL"

The fourth main attribute in the model, Reputation of the 3PL (RPT), has four sub-attributes; Market share (MS), Geographic spread and access to retailers (GS), Market knowledge (MK), and Experience in similar products (ESP). The pair-wise comparison for these four can be seen in Table 3.12.

Table 3.12: Pair – wise comparison matrix for the sub-attributes of "Reputation of the 3PL"

	MS	GS	MK	ESP
MS	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)	(2/3, 1, 2)
GS	(1/2, 1, 3/2)	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)
MK	(1, 1, 1)	(1, 1, 1)	(1, 1, 1)	(1/2, 1, 3/2)
ESP	(1/2, 1, 3/2)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)

The values of fuzzy synthetic extents with respect to "Reputation of the 3PL" are found as in Table 3.13.

Table 3.13: Summary of priority weights for the sub attributes of the "Reputation of the 3PL"

Sub attributes of the "Reputation of the 3PL"				
	Market Share	**Geographic Spread**	**Market Knowledge**	**Experience in Similar Products**
Weight	0.25	0.25	0.25	0.25

3.2.5.6 Evaluation of the sub-attributes with respect to "Long-term Relationships"

The last main attribute in the model, Long-term relationships (LTR), has six sub-attributes; Information sharing (INF), Willingness to use logistics manpower (WIL), Risk management (RM), Quality of management (QM), Compatibility (CPT), and Cost of relationship (COR). The pair-wise comparison for these six can be seen in Table 3.14.

Table 3.14: Pair – wise comparison matrix for the sub-attributes of "Long-term Relationships"

	INF	WIL	RM	QM	CPT	COR
INF	(1, 1, 1)	(1, 3/2, 2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)	(1/2, 1, 3/2)
WIL	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(2/3, 1, 2)
RM	(2/3, 1, 2)	(1, 3/2, 2)	(1, 1, 1)	(2/3, 1, 2)	(2/3, 1, 2)	(1, 1, 1)

	INF	WIL	RM	QM	CPT	COR
QM	(2/3, 1, 2)	(1, 3/2, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1/2, 1, 3/2)	(1, 1, 1)
CPT	(2/3, 1, 2)	(1, 3/2, 2)	(1/2, 1, 3/2)	(2/3, 1, 2)	(1, 1, 1)	(1/2, 1, 3/2)
COR	(2/3, 1, 2)	(1/2, 1, 3/2)	(1, 1, 1)	(1, 1, 1)	(2/3, 1, 2)	(1, 1, 1)

The values of fuzzy synthetic extents with respect to "Long-term relationships" are found as in Table 3.15.

Table 3.15: Summary of priority weights for the sub attributes of the "Long-Term Relationships"

	Sub attributes of the "Long-Term Relationships"					
	Information Sharing	**Willingness to Use Logistics Manpower**	**Risk Management**	**Quality of Management**	**Compatibility**	**Cost of Relationships**
Weight	0.17	0.14	0.17	0.17	0.18	0.17

3.2.5.7 Pair wise comparison of alternatives

For the third level, the pair-wise comparisons of alternatives regarding to the sub-attributes are calculated. Previously, in Table 3.3, qualifications of potential providers have been given. In this phase, according to Table 3.16, a methodology is developed to understand Table 3.3 better.

In applications it is convenient to work with TFNs because of their computational simplicity, and they are useful in promoting representation and information processing in a fuzzy environment. So, terms (very low, low, normal, high, very high) representing condition of alternative in Table 3.3 must be converted into triangular fuzzy numbers specifying the condition between alternatives according to Table 3.16.

Table 3.16: Reading table of qualifications of potential providers

Qualification of Alternative I	**Qualification of Alternative II**	**Result**
Very Low	Very Low	**Just Equal (JE)**
Low	Low	
Normal	Normal	
High	High	
Very High	Very High	
Very Low	Low	**Weakly More Important**

Qualification of Alternative I	Qualification of Alternative II	Result
Low	Normal	**(WMI)**
Normal	High	
High	Very High	
Very Low	Normal	**Strongly More Important (SMI)**
Low	High	
Normal	Very High	
Very Low	High	**Very Strongly More Important (VSMI)**
Low	Very High	
Very Low	Very High	**Absolutely More Important (AMI)**

For example; for the sub-attribute "Terms of Payment", the condition of alternative A is very low, alternative B is high, and alternative C is normal. In this case, according to Table 3.16, alternative B is very strongly more important than alternative A and weakly more important than alternative C. Additionally, alternative C is strongly more important than alternative A. In result, this situation is reflected to pair-wise comparison matrix like in Table 3.17 and Table 3.18.

High is not always better than normal or low or very low. As, the lower cost means to the higher points such as for the sub-attributes "Freight Price", "Extra Costs", and "Cost of relationship". For example, according to "Freight Price", alternative A, B, and C has taken low, normal, and high points, respectively. On the contrary to "terms of payment", in this case, alternative A is the most preferable. In other words, alternative A is weakly more important than alternative B and strongly more important than alternative C like in Table 3.17 and Table 3.18.

Table 3.17: An Example matrix of reading table

Main Criteria	Sub-Criteria	Alternatives	A	B	C
Cost of Service	Freight Price*	**A**	JE	WMI	SMI
		B	1/WMI	JE	WMI
		C	1/SMI	1/WMI	JE
	Terms of Payment	**A**	JE	1/VSMI	1/SMI
		B	VSMI	JE	WMI
		C	SMI	1/WMI	JE
	Extra Costs*	**A**	JE	1/WMI	1/SMI

Main Criteria	Sub-Criteria	Alternatives	A	B	C
		B	WMI	JE	1/WMI
		C	SMI	WMI	JE

*: The lower cost means to the higher points.

The pair-wise comparison for the alternatives regarding to sub attributes of "Cost of Service" can be seen in Table 3.18.

Table 3.18: Pair-wise comparison for the alternatives regarding to sub-attributes of "cost of service"

Main Criteria	Sub-Criteria	Alternatives	A	B	C
Cost of Service	Freight Price	A	(1, 1, 1)	(1, 3/2, 2)	(3/2, 2, 5/2)
		B	(1/2, 2/3, 1)	(1, 1, 1)	(1, 3/2, 2)
		C	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 1, 1)
	Terms of Payment	A	(1, 1, 1)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
		B	(2, 5/2, 3)	(1, 1, 1)	(1, 3/2, 2)
		C	(3/2, 2, 5/2)	(1/2, 2/3, 1)	(1, 1, 1)
	Extra Costs	A	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)
		B	(1, 3/2, 2)	(1, 1, 1)	(1/2, 2/3, 1)
		C	(3/2, 2, 5/2)	(1, 3/2, 2)	(1, 1, 1)

The values of fuzzy synthetic extents for alternatives with respect to sub-attributes of "Cost of Service" are found as in Table 3.19.

Table 3.19: Summary of priority weights for the alternatives regarding to "cost of service"

	Alternatives		
	A	B	C
Freight Price	0.60	0.35	0.05
Terms of Payment	0.00	0.63	0.37
Extra Costs	0.05	0.35	0.60

The pair-wise comparison for the alternatives regarding to sub attributes of "Financial Performance" can be seen in Table 3.20.

Table 3.20: Pair-wise comparison for the alternatives regarding to sub-attributes of "financial performance"

Main Criteria	Sub-Criteria	Alternatives	A	B	C
Financial Perf.	Flexibility in billing and payment	A	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)
		B	(1, 3/2, 2)	(1, 1, 1)	(1/2, 2/3, 1)
		C	(3/2, 2, 5/2)	(1, 3/2, 2)	(1, 1, 1)
	Financial stability	A	(1, 1, 1)	(1/2, 2/3, 1)	(1/2, 2/3, 1)
		B	(1, 3/2, 2)	(1, 1, 1)	(1, 1, 1)
		C	(1, 3/2, 2)	(1, 1, 1)	(1, 1, 1)
	Range of services provided	A	(1, 1, 1)	(2/5, 1/2, 2/3)	(1/3, 2/5, 1/2)
		B	(3/2, 2, 5/2)	(1, 1, 1)	(1/2, 2/3, 1)
		C	(2, 5/2, 3)	(1, 3/2, 2)	(1, 1, 1)

The values of fuzzy synthetic extents for alternatives with respect to sub-attributes of "Financial Performance" are found as in Table 3.21.

Table 3.21: Summary of priority weights for the alternatives regarding to "financial performance"

	Alternatives		
	A	B	C
Flexibility in billing and payment	0.05	0.35	0.60
Financial stability	0.16	0.42	0.42
Range of services provided	0.00	0.37	0.63

The pair-wise comparison for the alternatives regarding to sub attributes of "Operational Performance" can be seen in Table 3.22.

Table 3.22: Pair-wise comparison for the alternatives regarding to sub-attributes of "operational performance"

Main Criteria	Sub-Criteria	Alternatives	A	B	C
Operational Perf.	Quality	A	(1, 1, 1)	(1/2, 2/3, 1)	(1/2, 2/3, 1)
		B	(1, 3/2, 2)	(1, 1, 1)	(1, 1, 1)
		C	(1, 3/2, 2)	(1, 1, 1)	(1, 1, 1)
	IT capability	A	(1, 1, 1)	(2/5, ½, 2/3)	(1/2, 2/3, 1)
		B	(3/2, 2, 5/2)	(1, 1, 1)	(1, 3/2, 2)
		C	(1, 3/2, 2)	(1/2, 2/3, 1)	(1, 1, 1)
	Size and quality of fixed assets	A	(1, 1, 1)	(1, 3/2, 2)	(3/2, 2, 5/2)
		B	(1/2, 2/3, 1)	(1, 1, 1)	(1, 3/2, 2)

Main Criteria	Sub-Criteria	Alternatives	A	B	C
		C	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)	(1, 1, 1)
	Delivery performance	A	(1, 1, 1)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)
		B	(3/2, 2, 5/2)	(1, 1, 1)	(1, 3/2, 2)
		C	(1, 3/2, 2)	(1/2, 2/3, 1)	(1, 1, 1)
	Employee satisfaction level	A	(1, 1, 1)	(2/5,1/2, 2/3)	(1/2, 2/3, 1)
		B	(3/2, 2, 5/2)	(1, 1, 1)	(1, 3/2, 2)
		C	(1, 3/2, 2)	(1/2, 2/3, 1)	(1, 1, 1)
	Flexibility in operations and delivery	A	(1, 1, 1)	(1/3, 2/5, 1/2)	(2/5, 1/2, 2/3)
		B	(2, 5/2, 3)	(1, 1, 1)	(1, 3/2, 2)
		C	(3/2, 2, 5/2)	(1/2, 2/3, 1)	(1, 1, 1)

The values of fuzzy synthetic extents for alternatives with respect to sub-attributes of "Operational Performance" are found as in Table 3.23.

Table 3.23: Summary of priority weights for the alternatives regarding to "operational performance"

	Alternatives		
	A	**B**	**C**
Quality	0.16	0.42	0.42
IT capability	0.05	0.60	0.35
Size and quality of fixed assets	0.60	0.35	0.05
Delivery performance	0.05	0.60	0.35
Employee satisfaction level	0.05	0.60	0.35
Flexibility in operations and delivery	0.00	0.63	0.37

The pair-wise comparison for the alternatives regarding to sub attributes of "Reputation of the 3PL" can be seen in Table 3.24.

Table 3.24: Pair-wise comparison for the alternatives regarding to sub-attributes of "reputation of the 3PL"

Main Criteria	Sub-Criteria	Alternatives	A	B	C
Reputation of the 3PL	Market share	A	(1, 1, 1)	(1/2, 2/3, 1)	(1, 3/2, 2)
		B	(1, 3/2, 2)	(1, 1, 1)	(3/2, 2, 5/2)
		C	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)	(1, 1, 1)
	Geo. spread and access to	A	(1, 1, 1)	(1/2, 2/3, 1)	(1, 1, 1)
		B	(1, 3/2, 2)	(1, 1, 1)	(1, 3/2, 2)

Main Criteria	Sub-Criteria	Alternatives	A	B	C
	retailers	C	(1, 1, 1)	(1/2, 2/3, 1)	(1, 1, 1)
	Market knowledge	A	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)
		B	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)
		C	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)
	Experience in similar products	A	(1, 1, 1)	(1, 1, 1)	(2/5, 1/2, 2/3)
		B	(1, 1, 1)	(1, 1, 1)	(2/5, 1/2, 2/3)
		C	(3/2, 2, 5/2)	(3/2, 2, 5/2)	(1, 1, 1)

The values of fuzzy synthetic extents for alternatives with respect to sub-attributes of "Reputation of the 3PL" are found as in Table 3.25.

Table 3.25: Summary of priority weights for the alternatives regarding to "reputation of the 3PL"

	Alternatives		
	A	**B**	**C**
Market share	0.35	0.60	0.05
Geographic spread and access to retailers	0.22	0.56	0.22
Market knowledge	0.42	0.42	0.16
Experience in similar products	0.00	0.00	1.00

The pair-wise comparison for the alternatives regarding to sub attributes of "Long-term relationships" can be seen in Table 3.26.

Table 3.26: Pair-wise comparison for the alternatives regarding to sub-attributes of "long-term relationships"

Main Criteria	Sub-Criteria	Alternatives	A	B	C
Long Term Rel.	Information sharing	**A**	(1, 1, 1)	(1, 3/2, 2)	(1, 1, 1)
		B	(1/2, 2/3, 1)	(1, 1, 1)	(1/2, 2/3, 1)
		C	(1, 1, 1)	(1, 3/2, 2)	(1, 1, 1)
	Willingness to use logistics manpower	**A**	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)
		B	(1, 1, 1)	(1, 1, 1)	(1, 3/2, 2)
		C	(1/2, 2/3, 1)	(1/2, 2/3, 1)	(1, 1, 1)
	Risk management	**A**	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)
		B	(1, 3/2, 2)	(1, 1, 1)	(1/2, 2/3, 1)
		C	(3/2, 2, 5/2)	(1, 3/2, 2)	(1, 1, 1)
	Quality of management	**A**	(1, 1, 1)	(1/2, 2/3, 1)	(2/5, 1/2, 2/3)
		B	(1, 3/2, 2)	(1, 1, 1)	(1/2, 2/3, 1)

Main Criteria	Sub-Criteria	Alternatives	A	B	C
		C	(3/2, 2, 5/2)	(1, 3/2, 2)	(1, 1, 1)
	Compatibility	A	(1, 1, 1)	(2/5, 1/2, 2/3)	(2/5, 1/2, 2/3)
		B	(3/2, 2, 5/2)	(1, 1, 1)	(1, 1, 1)
		C	(3/2, 2, 5/2)	(1, 1, 1)	(1, 1, 1)
	Cost of relationship	A	(1, 1, 1)	(2/5, 1/2, 2/3)	(1/2, 2/3, 1)
		B	(3/2, 2, 5/2)	(1, 1, 1)	(1, 3/2, 2)
		C	(1, 3/2, 2)	(1/2, 2/3, 1)	(1, 1, 1)

The values of fuzzy synthetic extents for alternatives with respect to sub-attributes of "Long-term relationships" are found as in Table 3.27.

Table 3.27: Summary of priority weights for the alternatives regarding to "long-term relationships"

	Alternatives		
	A	**B**	**C**
Information sharing	0.42	0.16	0.42
Willingness to use logistics manpower	0.42	0.42	0.16
Risk management	0.05	0.35	0.60
Quality of management	0.05	0.35	0.60
Compatibility	0.00	0.50	0.50
Cost of relationship	0.05	0.60	0.35

4. RESULTS

The priority weights collected from each of pair-wise comparison matrices of main criteria, sub-criteria, and alternatives are input to the Table 4.1. In other words, the elements of Table 4.1 have been imported from the pair-wise comparison matrices.

If total weight of alternatives is compared, it can be seen that alternative B which has the highest priority weight is selected as a best logistics service provider. The logistics service provider B can fulfill the required demands of the FMCG case company.

The sequence of alternatives according to their importance weight is as follows: Alternative B, Alternative C, and Alternative A.

The results calculated shows that the main criteria *operational performance* is the most important factor for logistics service provider selection. Under operational performance, *IT capability* is the most important sub-criteria. The companies must pay full attention to develop IT capability besides the other factors.

Table 4.1: Priority weights of main and sub-attributes, and alternatives

Main Criteria	Main Criteria Point	Sub-Criteria	Sub-Criteria Point	Alternative A	Alternative B	Alternative C	Weight A	Weight B	Weight C
Cost of Service CST	**0.21**	Freight Price (FRP)	0.45	0.60	0.35	0.05	0.05670	0.03308	0.00473
		Terms of Payment (TOP)	0.41	0.00	0.63	0.37	0.00000	0.05424	0.03186
		Extra Costs (EXC)	0.14	0.05	0.35	0.60	0.00147	0.01029	0.01764
Financial Performance FP	**0.24**	Flexibility in billing and payment (FBP)	0.33	0.05	0.35	0.60	0.00396	0.02772	0.04752
		Financial stability (FS)	0.34	0.16	0.42	0.42	0.01306	0.03427	0.03427
		Range of services provided (RS)	0.33	0.00	0.37	0.63	0.00000	0.02930	0.04990
Operational Performance OP	**0.27**	Quality (QLT)	0.17	0.16	0.42	0.42	0.00734	0.01928	0.01928
		IT capability (IT)	0.19	0.05	0.60	0.35	0.00257	0.03078	0.01796
		Size and quality of fixed assets (FA)	0.16	0.60	0.35	0.05	0.02592	0.01512	0.00216
		Delivery performance (DP)	0.17	0.05	0.60	0.35	0.00230	0.02754	0.01607
		Employee satisfaction level (ESL)	0.16	0.05	0.60	0.35	0.00216	0.02592	0.01512
		Flexibility in operations and delivery (FOD)	0.15	0.00	0.63	0.37	0.00000	0.02552	0.01499
Reputation of the 3PL RPT	**0.12**	Market share (MS)	0.25	0.35	0.60	0.05	0.01050	0.01800	0.00150
		Geographic spread and access to retailers (GS)	0.25	0.22	0.56	0.22	0.00660	0.01680	0.00660
		Market knowledge (MK)	0.25	0.42	0.42	0.16	0.01260	0.01260	0.00480
		Experience in similar products (ESP)	0.25	0.00	0.00	1.00	0.00000	0.00000	0.03000

Main Criteria	Main Criteria Point	Sub-Criteria	Sub-Criteria Point	Alternative A	Alternative B	Alternative C	Weight A	Weight B	Weight C
Long-term Relationships LTR	**0.16**	Information sharing (INF)	0.17	0.42	0.16	0.42	0.01142	0.00435	0.01142
		Willingness to use logistics manpower (WIL)	0.14	0.42	0.42	0.16	0.00941	0.00941	0.00358
		Risk management (RM)	0.17	0.05	0.35	0.60	0.00136	0.00952	0.01632
		Quality of management (QM)	0.17	0.05	0.35	0.60	0.00136	0.00952	0.01632
		Compatibility (CPT)	0.18	0.00	0.50	0.50	0.00000	0.01440	0.01440
		Cost of relationship (COR)	0.17	0.05	0.60	0.35	0.00136	0.01632	0.00952
						TOTAL WEIGHT	**0.17008**	**0.44398**	**0.38594**

5. DISCUSSION

The proposed methodology provides for simplification of a complex multi-criteria decision-making problem. It may also be used to quantify many subjective judgments, which are necessary to evaluate different alternative providers. Another advantage of this methodology is that it not only supports group decision-making but also enables us to document the various considerations in the process of decision making.

Without decision support methodologies like AHP, managers might base their decisions on only a subset of important criteria while not understanding their relative importance and interactions.

There are some limitations of the approach. AHP assumes linear independence of criteria and alternatives. If there is dependence among the criteria, Analytic Network Process (ANP) (Saaty 2001) is more appropriate yet ANP requires far more comparisons which may be formidable in practical decision environment. This is a new area of research to explore.

AHP is appropriate whenever a goal is clearly stated and a set of relevant criteria and alternatives are available. When there are quite a few criteria involved, AHP is among very few multiple criteria approach capable of handling so many criteria, especially if some of the criteria are qualitative. Because human decision-making process usually contains fuzziness and vagueness, the fuzzy AHP is adopted to solve the problem. A well-organized fuzzy AHP information system is constructed to facilitate the solving process.

This documentation is useful if the results are to be communicated to various interest groups. For the example undertaken in this study, the results indicate that alternative B is the first choice of the case company. This may be attributed to its advanced IT, supply chain, and change management capabilities. The expertise of altenative B in the framing of transportation and distribution policy also supports this result. It is pertinent

here to discuss the priority values of the determinants, which influence this decision. From Table 3.5, it is observed that operational performance (27 percent) is the most important determinant in the selection of a logistics service provider. It is followed by financial performance (24 percent), cost of service (21 percent), long-term relationships (16 percent), and reputation of the 3PL (12 percent). According to these results, logistics service providers ought to improve their operational and financial performance firstly providing advanced technology offerings around strategy, planning, collaboration, data management, decision support, integration, and flexibility.

Although the model has been illustrated for three distinct alternative providers, it is capable of comparing more than three providers at the cost of complexity. It needs to be emphasized here that despite using a sound algorithm for systematic decision-making, care must be taken in the application of the fuzzy AHP approach. For example, in its application, the user has to compare the prospective providers on a number of pair-wise comparison matrices. In these comparisons, the user must verify the capabilities of the providers and should not solely rely on the information given by the prospective providers. Experts recommend that the user companies should evaluate the providers by what they have done and not by what they plan to do. Although in this case the input to the pair-wise comparison matrices is based on the responses to RFP and visits of the logistics manager to the sites of the provider companies, the biasing of the decision maker towards a particular provider cannot be ruled out. To avoid such situations, group decision-making techniques should be used. For example, brainstorming and sharing of ideas and insights often lead to a better understanding of the issues than would be possible for a single decision-maker.

Scenario building or the Delphi method may also be used for the pair-wise comparisons. In the case of a group decision making process, consensus may be reached by agreeing on the geometric means of individual judgments. In the absence of consensus, voting may also be conducted to arrive at a more acceptable value. Compared to low-level enablers, consensus is more desirable for determinants and dimension as the higher level of the fuzzy AHP model.

Use of software and decision support systems may also reduce the complexities in implementing the group decision-making. In the light of the results obtained for the case

company, it may be noted that these results are valid only for the case company in its own decision environment and should not be generalized to establish the supremacy of one provider over the others. Further, the application of proposed methodology may require significant time and resources from managers and decision-makers. Yet, when seeking to invest in a long-term logistics-outsourcing contract that can potentially reach millions of dollars, a structured analysis, which is provided by this methodology, may help to reduce the risk of poor investment decisions.

6. CONCLUSION

Logistics service provider selection process becomes increasingly important in today's complex environment. The selection process involves the determination of quantitative and qualitative factors to select the best possible provider. Decision-makers face up to the uncertainty and vagueness from subjective perceptions and experiences in the decision-making process. Multi-criteria decision systems need experts in different areas. Fuzzy theory can be used in many decision making areas like that. Fuzzy AHP approach seems to be particularly effective in reducing the uncertainty in the determination of the relative weight given to the different criteria and in determining the impact of each alternative provider on the attributes considered.

In this study logistics service provider selection via extent fuzzy AHP has been proposed. The decision criteria are cost of service, financial performance, operational performance, reputation of the 3PL, and long-tern relationships. These criteria were evaluated to obtain the preference degree associated with each logistics service provider alternative for selecting the most appropriate one for the company. By the help of the extent fuzzy approach, the ambiguities involved in the data could be effectively represented and processed to make a more effective decision. As a result of this study alternative B is determined as the best logistics service provider which has the highest priority weight. The company management found the application and results satisfactory and decided to work with alternative B.

The major contribution of this paper lies in the development of a comprehensive methodology, which incorporates diversified issues, for the selection of a logistics service provider. The paper also provides for a review of the issues, which influence the selection of a logistics service provider. The fuzzy AHP approach, as a part of this methodology, not only leads to a logical result but also enables the decision-makers to visualize the impact of various criteria in the final result.

At a time when outsourcing of logistics activities has become a global trend, this research paper provides an insight into the various aspects of logistics outsourcing. The proposed methodology serves as a guideline to the logistics managers in outsourcing-related decisions. The AHP approach is capable of taking into consideration both qualitative and quantitative criteria. Similar AHP-based models may also be developed in other contexts as well. But, as the development and evaluation of these models demand significant time and efforts from the decision-makers in the formation of pair-wise comparison matrices, these should be used for long-term strategic decisions only where the investments made in the lengthy and cumbersome process of decision-making are recovered in due course of time. Further, though the technique is computationally intensive, the benefits of risk reduction will outweigh the cost and time.

As far as the selection of 3PL providers is concerned, the key lessons were as follows:

i. Proper care and managerial support is required for defining the objectives and 3PL requirements of the company, having an efficient implementation plan for the integration process, and consistently evaluating and monitoring the 3PL provider.

ii. The utilization of utility functions for quantitative evaluations and ratings and step functions for qualitative evaluations improved the efficiency and the visibility in the managerial decision-making process.

As far as the application of fuzzy AHP is concerned, this research highlighted the following advantages and disadvantages:

i. The hierarchical representation of the 3PL selection problem allowed the decision-makers to easily observe the effect of the changes of the priority in the upper levels on the priority of criteria at the lower levels.

ii. The analysis helped the company to structure the problem with its differing aspects rather than only financial considerations.

iii. The approach facilitated conflict resolution process among departments and brought objectivity to decisions via the analytical approach. However, the process is a difficult and time-consuming one to manage.

iv. The decision-makers assumed that the performance of the 3PL providers was known with certainty when making their comparative judgments. Thus, the method disregarded the risk and uncertainty in assessing the 3PL providers' true performance.

The project also highlighted the extent to which 3PL providers need to adapt to the rapidly changing requirements of their customers. Specifically, companies wishing to compete in the provision of 3PL services need to consider the following key areas of investment and service provision:

i. Faced with more demanding customer expectations and sophisticated requirements for technology based and strategic supply chains 3PL providers ought to be equipped with advanced technology offerings around strategy, planning, collaboration, data management, decision support, and integration.

ii. 3PL companies need to improve their performance measurement processes to address broader supply chain requirements, international trade, and partner integration.

iii. With continuing pressure on improving their relationship skills, 3PLs should focus more on CRM activities in an effort to exceed customer expectations.

This study raises several important issues that warrant further research. For example, the model may also be subjected to a sensitivity analysis. Further evaluation and refinement of the model using additional field studies may prove beneficial in developing an intelligent system, which would advise the decision-makers about the low significance of certain main criteria, sub-criteria, and alternatives. Accordingly the decision attributes with low significance value may be dropped from the model, resulting in its simplification.

Finally, fuzzy AHP excel program can be developed and be made more user-friendly on the basis of this model.

For further research, other fuzzy multi-criteria evaluation methods that have been recently proposed in a fuzzy environment like fuzzy TOPSIS or fuzzy outranking

methods can be used and the obtained results can be compared with the ones found in this paper.

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APPENDICES

Appendix A.1 Key logistics outsourcing related findings since 1999 to present

Author(s)	Key logistics outsourcing related findings
BERGLUND/VAN LAARHOVEN/SHARMAN/WANDEL (1999)	3PLs can add value by creating operational efficiencies and/or by sharing resources between customers.
BHATNAGAR/SOHAL/MILLEN (1999)	Cost saving, customer satisfaction, and flexibility (customization) were the most important reasons for logistics outsourcing. By developing goals and selection criteria, user companies will be in a better position to determine which provider would best suit their needs.
BOYSON/CORSI/DRESNER/ RABINOVICH (1999)	The outsourcing of logistics functions has proven to be effective in helping firms to achieve competitive advantage, improve their customer service levels and reduce their overall logistics costs.
SUM/TEO (1999)	3PL companies following a "cost and differentiation" strategy consistently exhibit stronger performance metrics than do other strategic types.
LEWIS/TALALAYEVSKY (2000)	Significant improvements in information technology support the feasibility of centralized markets, such as those offered by 3PLs.
SKJOETT - LARSEN (2000)	Two theories, involving transactions costs and the network approach, can explain the development of 3PL.
VAN HOEK (2000)	Traditional third - party logistics services such as warehousing and transportation have become, to some extent, commoditized.
VAN LAARHOVEN/ BERGLUND/PETERS (2000)	Some outsourcing relationships are perceived by the shipper as more successful than others. Some success factors are: well defined requirements, procedures, systems, and close relationships

Author(s)	Key logistics outsourcing related findings
BAUMGARTEN/WALTER (2000)	Logistics outsourcing is a major trend driven by the firms' desire to reduce costs and to increase flexibility and service levels.
BOLUMOLE (2001)	The capability of service providers to facilitate supply chain solutions is largely influenced by four main factors, which in turn significantly determine their role in the supply chain. The nature of the client - provider relationship is one of these factors.
PERSSON/VIRUM (2001)	Given the pressures in the industry and the individual strategic position, the strategic choices are limited, leading to some dominating strategic directions.
STONE (2001)	Expansions has proved demanding and, for many U.K. logistics service providers, the single European market has yet to fulfill its initial promise.
ANDERSSON/NORMAN (2002)	An eight-point plan for the selection and implementation of logistics outsourcing services.
BAUMGARTEN/THOMS (2002)	The degree of logistics outsourcing in German firms is high and still increasing.
LARSON/GAMMELGAARD (2002)	Danish logistics providers tend to be "niche firms", focusing on the domestic market and limited sets of customers by industry.
LIEB/MILLER (2002)	Users are most satisfied with the impact of these arrangements on logistics costs, logistics service levels and customer service.
DEEPEN (2003)	Reducing logistics costs and increasing logistics performance are main drivers of logistics outsourcing - contextual factors such as asset specificity determine the respective advantages and disadvantages.

Author(s)	Key logistics outsourcing related findings
KNEMEYER/CORSI/MURPHY (2003)	Exploratory findings show that developing closer relationships between shipper and 3PL create increased costs, but at the same time promise benefits
LANGLEY/ALLEN/COLOMBO (2003)	The marketplace for 3PL services continues to change - both users and providers are becoming more capable while the expectations of each other are rising. While more productive and meaningful 3PL customer-supplier relationships evolve, a gap exists between what customers receive and what they expect to receive.
STANK/GOLDSBY/VICKERY/ SAVITSKIE (2003)	Relational performance by 3PLs was found to be the single most important factor in engendering customer satisfaction.
LANGLEY/ALLEN/DALE (2004)	While 3PL users generally feel that their relationships with 3PL providers are successful, they are able to find areas of improvement, such as implementing capable IT, instituting effective management and relationship processes and integrating services and technologies globally. Customer demands for performance and sophistication are accelerating.
KNEMEYER/MURPHY (2004)	Various relationship marketing dimensions (trust, communication, opportunistic behavior etc.) influence the buyer's perception of 3PL performance.
ENGELBRECHT (2004)	Outsourcing performance is explained by the degree of outsourcing only to a limited extent. The implementation of the outsourcing project has a significantly higher explanatory value

Author(s)	Key logistics outsourcing related findings
AKTAS/ULUENGİN (2005)	Turkish businessmen think that they should do their business themselves and they are not aware of the benefits of outsourcing logistics activities. In fact, in selecting the transportation carrier, they consider different criteria but the general tendency is either to select the carrier that has a good reputation and/or the one which is easy to collaborate with.
STRAUBE/PFOHL/GÜNTHER/ DANGELMAIER (2005)	Logistics providers must cope with growing uncertainty, increasing cost pressure, and more complex value chains and at the same time fulfill increasingly changing customer demands
KNEMEYER/MURPHY (2005)	Relationship characteristics such as communication with the 3PL provider have a more profound impact on logistics outsourcing relationship outcomes than customer attributes such as firm size, number of functions outsourced, and the number of 3PL relationships
LANGLEY/DORT/ANG/SYKES (2005)	3PL users continue to view a collaborative partnership approach with their 3PL providers as key to improving the user - company 3PL - performance. Different to past surveys, pricing has become the most important attribute in selecting a 3PL provider.
GÖL/ÇATAY (2007)	3PL providers in Turkey must improve their capabilities and act proactively in providing value-adding services as the companies are becoming more demanding in their expectations in building strategic relationships.
JHARKHARIA/SHANKAR (2007)	Selection of logistics service provider: An analytic network process. The ANP approach not only leads to a logical result but also enables the decision-makers to visualize the impact of various criteria in the final result.

Author(s)	Key logistics outsourcing related findings
QURESHI/KUMAR/KUMAR (2007)	Top management from both shippers as well as LSPs should focus, on improving on the enablers such as trust or commitment, direct assistance, long term contract, evaluation of supplier performance, practices of TQM and JIT to add distinctive values, and top management support.

Appendix A.2 Questionnaire forms used to facilitate comparisons of main and sub-attributes

Read the following questions and put check marks on the pair wise comparison matrices. If an attribute on the left is more important than the one matching on the right, put your check mark to the left of the importance "Equal" under the importance level you prefer. If an attribute on the left is less important than the one matching on the right, put your check mark to the right of the importance "Equal" under the importance level you prefer.

QUESTIONS

With respect to the overall goal "selection of the best logistics service provider",

Q1. How important is *cost of service (CST)* when it is compared with *financial performance (FP)*?

Q2. How important is *cost of service (CST)* when it is compared with *operational performance (OP)*?

Q3. How important is *cost of service (CST)* when it is compared with *reputation of the 3PL (RPT)*?

Q4. How important is *cost of service (CST)* when it is compared with *long-term relationships (LTR)*?

Q5. How important is *financial performance (FP)* when it is compared with *operational performance (OP)*?

Q6. How important is *financial performance (FP)* when it is compared with *reputation of 3PL (RPT)*?

Q7. How important is *financial performance (FP)* when it is compared with *long-term relationships (LTR)*?

Q8. How important is *operational performance (OP)* when it is compared with *reputation of the 3PL (RPT)*?

Q9. How important is *operational performance (OP)* when it is compared with *long-term relationships (LTR)*?

Q10. How important is *reputation of the 3PL (RPT)* when it is compared with *long-term relationships (LTR)*?

With respect to: the overall goal		Importance (or preference) of one main-attribute over another											
Questions	**Attributes**	Absolutely More Important	Very Strongly More Important	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More Important	Absolutely More Important	**Attributes**
Q1	**CST**												**FP**
Q2	**CST**												**OP**
Q3	**CST**												**RPT**
Q4	**CST**												**LTR**
Q5	**FP**												**OP**

Q6	**FP**												**RPT**
Q7	**FP**												**LTR**
Q8	**OP**												**RPT**
Q9	**OP**												**LTR**
Q10	**RPT**												**LTR**

With respect to the main attribute "cost of service (CST)",

Q11. How important is *freight price (FRP)* when it is compared with *terms of payments (TOP)*?

Q12. How important is *freight price (FRP)* when it is compared with *extra costs (EXC)*?

Q13. How important is *terms of payments (TOP)* when it is compared with *extra cost (EXC)*?

With respect to: Cost of service		Importance (or preference) of one sub-attribute over another											
Questions	**Attributes**	Absolutely More Important	Very Strongly More Important	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More Important	Absolutely More Important	**Attributes**
Q11	**FRP**												**TOP**
Q12	**FRP**												**EXC**
Q13	**TOP**												**EXC**

With respect to the main attribute "financial performance (FP)",

Q14. How important is *flexibility in billing and payment (FBP)* when it is compared with *financial stability (FS)*?

Q15. How important is *flexibility in billing and payment (FBP)* when it is compared with *range of services provided (RS)*?

Q16. How important is *financial stability (FS)* when it is compared with *range of services provided (RS)*?

With respect to: Financial performance		Importance (or preference) of one sub-attribute over another											
Questions	**Attributes**	Absolutely More Important	Very Strongly More Important	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More Important	Absolutely More Important	**Attributes**
Q14	**FBP**												**FS**
Q15	**FBP**												**RS**

Q16	**FS**												**RS**

With respect to the main attribute "operational performance (OP)",

Q17. How important is *quality (QLT)* when it is compared with *information technology capability (IT)*?

Q18. How important is *quality (QLT)* when it is compared with *size and quality of fixed assets (FA)*?

Q19. How important is *quality (QLT)* when it is compared with *delivery performance (DP)*?

Q20. How important is *quality (QLT)* when it is compared with *employee satisfaction level (ESL)*?

Q21. How important is *quality (QLT)* when it is compared with *flexibility in operations and delivery (FOD)*?

Q22. How important is *information technology capability (IT)* when it is compared with *size and quality of fixed assets (FA)*?

Q23. How important is *information technology capability (IT)* when it is compared with *delivery performance (DP)*?

Q24. How important is *information technology capability (IT)* when it is compared with *employee satisfaction level (ESL)*?

Q25. How important is *information technology capability (IT)* when it is compared with *flexibility in operations and delivery (FOD)*?

Q26. How important is *size and quality of fixed assets (FA)* when it is compared with *delivery performance (DP)*?

Q27. How important is *size and quality of fixed assets (FA)* when it is compared with *employee satisfaction level (ESL)*?

Q28. How important is *size and quality of fixed assets (FA)* when it is compared with *flexibility in operations and delivery (FOD)*?

Q29. How important is *delivery performance (DP)* when it is compared with *employee satisfaction level (ESL)*?

Q30. How important is *delivery performance (DP)* when it is compared with *flexibility in operations and delivery (FOD)*?

Q31. How important is *employee satisfaction level (ESL)* when it is compared with *flexibility in operations and delivery (FOD)*?

With respect to: Operational performance		Importance (or preference) of one sub-attribute over another											
Questions	**Attributes**	Absolutely More Important	Very Strongly More Important	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More Important	Absolutely More Important	**Attributes**
Q17	**QLT**												**IT**
Q18	**QLT**												**FA**
Q19	**QLT**												**DP**

Q20	**QLT**												**ESL**
Q21	**QLT**												**FOD**
Q22	**IT**												**FA**
Q23	**IT**												**DP**
Q24	**IT**												**ESL**
Q25	**IT**												**FOD**
Q26	**FA**												**DP**
Q27	**FA**												**ESL**
Q28	**FA**												**FOD**
Q29	**DP**												**ESL**
Q30	**DP**												**FOD**
Q31	**ESL**												**FOD**

With respect to the main attribute "reputation of the logistics service provider (RPT)",

Q32. How important is *market share (MS)* when it is compared with *geographic spread and access to retailers (GS)*?

Q33. How important is *market share (MS)* when it is compared with *market knowledge (MK)*?

Q34. How important is *market share (MS)* when it is compared with *experience in similar products (ESP)*?

Q35. How important is *geographic spread and access to retailers (GS)* when it is compared with *market knowledge (MK)*?

Q36. How important is *geographic spread and access to retailers (GS)* when it is compared with *experience in similar products (ESP)*?

Q37. How important is *market knowledge (MK)* when it is compared with *experience in similar products (ESP)*?

With respect to: Reputation of the logistics service provider		Importance (or preference) of one sub-attribute over another											
Questions	**Attributes**	Absolutely More Important	Very Strongly More Important	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More Important	Absolutely More Important	**Attributes**
Q32	**MS**												**GS**
Q33	**MS**												**MK**
Q34	**MS**												**ESP**
Q35	**GS**												**MK**
Q36	**GS**												**ESP**
Q37	**MK**												**ESP**

With respect to the main attribute "long-term relationships (LTR)",

Q38. How important is *information sharing (INF)* when it is compared with *willingness to use logistics manpower (WIL)*?

Q39. How important is *information sharing (INF)* when it is compared with *risk management (RM)*?

Q40. How important is *information sharing (INF)* when it is compared with *quality of management (QM)*?

Q41. How important is *information sharing (INF)* when it is compared with *compatibility with the users (CPT)*?

Q42. How important is *information sharing (INF)* when it is compared with *cost of relationship (COR)*?

Q43. How important is *willingness to use logistics manpower (WIL)* when it is compared with *risk management (RM)*?

Q44. How important is *willingness to use logistics manpower (WIL)* when it is compared with *quality of management (QM)*?

Q45. How important is *willingness to use logistics manpower (WIL)* when it is compared with *compatibility with the users (CPT)*?

Q46. How important is *willingness to use logistics manpower (WIL)* when it is compared with *cost of relationship (COR)*?

Q47. How important is *risk management (RM)* when it is compared with *quality of management (QM)*?

Q48. How important is *risk management (RM)* when it is compared with *compatibility with the users (CPT)*?

Q49. How important is *risk management (RM)* when it is compared with *cost of relationship (COR)*?

Q50. How important is *quality of management (QM)* when it is compared with *compatibility with the users (CPT)*?

Q51. How important is *quality of management (QM)* when it is compared with *cost of relationship (COR)*?

Q52. How important is *compatibility with the users (CPT)* when it is compared with *cost of relationship (COR)*?

With respect to: Long-term relationships		Importance (or preference) of one sub-attribute over another											
Questions	**Attributes**	Absolutely More Important	Very Strongly More Important	Strongly More Important	Weakly More Important	Equally Important	Just Equal	Equally Important	Weakly More Important	Strongly More Important	Very Strongly More Important	Absolutely More Important	**Attributes**
Q38	**INF**												**WIL**
Q39	**INF**												**RM**
Q40	**INF**												**QM**
Q41	**INF**												**CPT**
Q42	**INF**												**COR**

Q43	**WIL**												**RM**
Q44	**WIL**												**QM**
Q45	**WIL**												**CPT**
Q46	**WIL**												**COR**
Q47	**RM**												**QM**
Q48	**RM**												**CPT**
Q49	**RM**												**COR**
Q50	**QM**												**CPT**
Q51	**QM**												**COR**
Q52	**CPT**												**COR**

THANK YOU FOR YOUR PATIENT and SUPPORT…

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