DEVELOPMENT OF OUTSOURCING DECISION MODELS FOR SMALL AND MEDIUM SIZED MANUFACTURING COMPANIES

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I dedicate this thesis to my late father Kala Khan (May God bless his soul).

The dreams of my father,

the prayers of my mother,

the support of my kind wife and

the inspirations of my academic mentor

made this achievement possible by the will of Almighty God.

ABSTRACT

Global markets are continuously developing and becoming extremely competitive. The manufacturing organisations are improving their capabilities and responsiveness to satisfy their customer demands. Due to this dynamic change, most of the developed countries, particularly the United Kingdom, Europe and the United States have witnessed a sharp increase in outsourcing.

A literature search revealed weakness in outsourcing, due to the lack of suitable decision models and frameworks. However, limited research has been carried out in the area of outsourcing of manufacturing in small and medium sized companies.

The main aims of this research are formulating appropriate decision models for small and medium sized companies; in particular, those that have been outsourcing, or planning to outsource, their manufacturing activities.

The outsourcer's criteria for outsourcee selection for small and medium sized manufacturing companies are chosen after analysing the data obtained through the literature survey, questionnaire survey and personal interviews. Next, a model is formulated for numerical evaluation of outsourcer's criteria for outsourcee selection. Then, a second model for outsourcee (supplier) selection is formulated. The model comprises analytical hierarchy process, cluster analysis and criteria scoring of outsourcee. In the selection process of the most appropriate outsourcee, three elements has to be considered; the previously defined i) vector of important criteria resulted from the information analysis of literature survey, questionnaire and interviews, ii) the specific criteria ranking scoring identified by a particular outsourcer company and iii) the fulfilment of both general criteria (business / market) and specific criteria (outsourcer company) by the potential outsourcees. The outsourcee that achieves the highest total score based on the priority weights of each criterion and sub-criterion in the model may be considered the most suitable.

The numerical results of the second model are compared against the empirical outcome of a test case is satisfactory. The developed method is consistent, faster and objective.

A further model for drawing up and implementing a manufacturing level agreement was formulated, based on the information collected through the literature survey, questionnaire survey and interviews. The above models were presented to the managers of the companies and are found to be useful according to the feedback provided by them. They will be using the models in stages, subject to the resource availability.

Keywords:

Analytical Hierarchy Process, Cluster Analysis, Decision, Decision Model, Manufacturing, Outsourcee, Outsourcer, Outsourcing

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S_{k82}	S_{DSd}	Ranking Score of Design Standard for kth outsourcee
S_{k83}	S_{MSd}	Ranking Score of Material Standard for kth outsourcee

AHP	Analytical Hierarchical Process
BPO	Business Process Outsourcing
CA	Cluster Analysis
CE	Cost Effectiveness
CmC	Competitive Cost
CnC	Consistent Cost
DCn	Delivery Consistency
DD	Delivery Documentation
DLT	Delivery Lead Time
DSd	Delivery Standard
FA	Financial Operation Ability
FlCh	Flexibility to Adjust Changes
GRLS	Good Relationships with Linked Suppliers
HdWr	Hardware
IDLS	Information Declaration about Linked Suppliers
IPLS	Linked Suppliers Participate in Improvements
IT	Information Technology
MBP	Management & Business Professionalism
MLA	Manufacturing Level Agreement
MSd	Material Standard
Nbcy	Not Subject to Receivership or Bankruptcy
NoLS	Link with a Number of Suppliers
OCE	Outsourcing Cycle Effectiveness
ODI	Outsourcing Determinant Index
OEL	Organisational and Environmental Laws
OTD	On-Time Delivery
PlCp	Personnel Capability
PrCp	Process Capability
PSd	Product Standard
QSdLS	Linked Suppliers Comply Quality Standards
Qu	Quality
Re	Reputation
ResCh	Responsiveness to Change
SCom	Secure Communication System
SME	Small and medium-sized Enterprise
SuC	Sustainable Cost
TIB	Time (Duration) in Business by Outsourcee
TMA	Technology and Manufacturing Ability
TSCR	Trained Staff for Relationship Development
UBL	Outsourcee Understands Business Rules

UCBR Understanding of Customer's Requirement

UIBL Outsourcee Understands Intellectual Property Protection Law

P_{bm} Price standard/benchmark

P_{qf} Quoted fair price

P_{rf} Required fair price

C_v Cost variation

C_a Actual cost

C_e Estimated cost

K_{qa} Quality assurance

n_{rej} Number of rejected parts

n_{rec} Number of parts received

K_{dela} Delivery assurance

$n_{on-time}$ Number of on-time deliveries

$n_{t-delivery}$ Number of total deliveries

m Number of available candidate outsourcees (suppliers)

a Attribute/Criteria/Characteristics/Specification

n Number of attributes considered for assessing outsourcee capabilities

N Number of advisers/decision-makers (Decision-makers)

W_N Weight value allotted by N_{th} decision-maker to a candidate outsourcee's (supplier) criteria

θ_{ps} Phase difference between required criteria value vector and the outsourcee's criteria value vector

W_p Required criteria decision vector demanded by the outsourcer

W_s Criteria weight vector assigned to a particular supplier (candidate outsourcee)

W_{ps} Euclidean distance between the required criteria weight value vector demanded by outsourcer and the criteria weight value vector assigned to a particular supplier (candidate outsourcee)

$\emptyset_i$ Number of decision-makers in a cluster that holds i_{th} decision-makers

$\propto_i$ Weight of the i_{th} decision-maker

ω_i^c= Priority weight of criterion, i= Criterion's number (i = 1,2, ... ,8)

ω_{ij}^{sc}= Priority weight of sub-criterion, j= Number of sub-criterion (j = 1,2, ... ns; j $\in I$)

S	Outsourcee's ranking score
k	Candidate outsourcee's number $(k = 1,2, \ldots m; k \in I)$
ns	The total number of sub-criteria for certain criterion
Dafier	SUPD $k = 1$
Kinroad	SUPK $k = 2$
WUXI	SUPW $k = 3$
Baoying	SUPB $k = 4$

GLOSSARY

Framework: A set of assumptions, concepts, guidelines and practices that constitute a fundamental structure for solutions to a number of related problems.

Model: A schematic description of a system, theory or phenomenon that includes generic procedures for data abstraction or performing specific activities.

Outsourcee: The outside provider (supplier) to whom the responsibilities are transferred.

Outsourcer: The organisation that transfers its internal activities and decision-making responsibilities to external providers.

Outsourcing: The moving of some of the organisation's internal activities and decision-making responsibilities to outside provide

Chapter 1

INTRODUCTION

A number of attempts have been made by various authors to develop models and frameworks for outsourcing in the areas of information technology (IT), service sector and business process outsourcing (BPO). The outsourcing models and frameworks have also been proposed for diverse areas such as 'outsourcing of information technology', 'outsourcing of asset management services', 'assessing outsourcing risks' and 'Virtual IDM Model for Outsourcing Chip Design and Manufacturing'. However, despite obvious advantages, the outsourcing operations have not been successful due to the selection of an inappropriate participant (outsourcee), and/or lack of proper operational management of the (outsourcing operations) process, and/or not well-written outsourcing contracts.

Following the outsourcing trend in IT, services sector and BPO, the manufacturing sector has been employing outsourcing extensively. The literature review identified that very little work has been done to develop outsourcing models and frameworks to help manufacturing small and medium sized companies.

This thesis fills the gap in the literature by formulating outsourcing models for small and medium sized manufacturing companies. The outsourcee selection model for manufacturing could not be designed without the identification of suitable selection criteria. A model is also formulated for providing guidelines for drawing up an appropriate manufacturing level agreement (MLA) and its implementation for small and medium sized manufacturing companies.

The first section of this chapter presents a background of the outsourcing and identifies its problems. The following sections are the literature survey, definition of problem, research questions and hypothesis and the aims of the thesis. The final section presents the outline of the thesis.

1.1 BACKGROUND

Outsourcing is the transfer of repetitive routine tasks or services to an external source, or paying other companies to perform all, or parts of a job. Outsourcing is also defined as the procurement of products or services from sources that are external to the organisation. It is the moving of some of the organisation's internal activities and decision responsibilities to outside providers (Schniederjans *et al*. 2004).

Organisations practising outsourcing cease to carry out various functions outside its 'core' activity, and instead purchase the services or products concerned from external parties. Outsourcing involves the restructuring of the organisation concerned, around a distinction between its core activities and services provided by an external supplier. Outsourcing is based on an internal process of redefinition of production activities that are usually classified as 'core' activities, and 'non-core' activities. Initially, only 'non-core' activities were outsourced, and nowadays a combination of both 'non-core' and 'core' activities are outsourced.

Outsourcing is furthermore a multi-dimensional system, involving customer, company, supplier, transporter / shipper and storage provider. If the system is not operated carefully it ends up as inefficient, and ultimately fails.

Increasing pressure on manufacturing companies for cutting costs, for introducing product variety continuously at short intervals, and searching for the best, has persuaded manufacturers to adopt outsourcing. Chappell (1997) reported on one of Nissan's outsourcing operations that the outsourcee companies do not have the ability to deliver the capability of matching the colour of the plastic, whereas Nick (2006) stated that the outsourcing process is unable to deliver the highest standard, and Greg (2006) reported that in outsourcing manufacturing to China, quality is the main concern. It was identified that companies practising outsourcing are not satisfied with the outcome of their outsourcing operations. The existing outsourcing frameworks and models do not offer a complete analysis of the outsourcing activities and as a result the solutions proposed are only partial. Hence, this thesis tries to address the above mentioned limitations by developing decision models for identifying and ranking the market criteria, selecting an appropriate supplier

and defining guidelines for writing and implementing an outsourcing contract. The initial data used in the thesis was collected from the literature surveys, questionnaires, interviews and case studies. The positive feedback received from the companies involved seems to indicate the practicality of this research.

1.2 LITERATURE REVIEW

Some of the outsourcing models and frameworks are briefly discussed below:

The outsourcing decision model developed by Akomode *et al.* (1998) used the analytical hierarchy process (AHP) and modelled risk elements. The model was created for Information Technology (IT) and used both qualitative and quantitative criteria. The overall objective of the model was achieved by evaluating the total importance weight assigned to each of the suppliers. The supplier who scored the highest weight was the most suitable.

McIvor's (2000) sourcing framework was structured for evaluating outsourcing decisions. It was developed based on three key aspects: the value chain perspective, core competency thinking and the impact of supply base. It resembles a flow chart and all the stages are clearly explained. The framework consists of four sequential stages. In the first stage core and non-core activities of the organisation are identified. In the next stage, an analysis of the competencies of the company in the core activities, in relation to potential external sources for benchmarking, is carried out. In the third stage, an analysis is carried out to measure the actual and the potential costs involved in sourcing the activity internally or externally. In the final stage, a relationship analysis is carried out.

Visser *et al.* (2000) developed a composite outsourcing decision framework which consisted of three main components. The first component focuses on developing the unique contextual factors associated with each decision. It involves both internal and external factors, which can be either quantifiable or non-quantifiable criteria. The second component considers the strategic implications of deciding to outsource. The strategic and structural dimensions are considered. The third component of the model concerns costs and is examined by transaction cost theory. Two types of costs are considered, which are

production cost and coordination or transaction cost. The framework can be applied to any area of outsourcing. In order to simplify the decision process, the decision elements are divided into three sections. The outcome of each section is combined for the final decision. The composite approach was beneficial while designing the outsourcing models for manufacturing. The outsourcee selection criteria were split into qualitative and quantitative criteria. The qualitative criteria are normally non-quantifiable. However, using AHP the qualitative criteria can be evaluated relatively. The process is followed in stages, similar to those proposed in the composite model.

Barragan *et al.* (2003) proposed a strategic sourcing framework for new product development. It consists of four stages. In the first stage, a multidimensional expert team from key knowledge areas of architecture, business, supply chain and procurement is assembled. In the following stage, strategic position is analysed by comparing the competitive advantage content versus internal capability. In the next stage, an analysis of the desired level of control over the activity being considered for outsourcing is carried out. In the last stage, a strategy is developed to enhance capabilities that are needed and aligned with the organisation's long-term objectives.

Zeng (2003) proposed a model for outsourcing of the procurement process and a logistics cost evaluation framework in global sourcing processes. The model consists of five distinct stages: Investigation and Tendering, Evaluation, Supplier Selection and Development, Implementation, Performance Measurement and Continuous Improvement. It begins from identification of core and non-core activities, and ends with continuous improvement. The procurement model contains the details of all of the outsourcing activities. The example of this model was found to be very helpful in formulating models in the initial stages of the research.

The framework also consists of five stages, beginning from examining the logistics cost associated with sourcing, and ending by calculating the annual total logistics cost for moving material. In addition to the cost matrix, the model also calculates series of percentages of the logistics cost, relative to the values of raw materials, value-added services, or the completed parts respectively. These percentages are useful in evaluating the effectiveness of the sourcing alternatives. The information from the logistics cost

evaluation framework was used in formulating quantitative expressions for evaluating outsourcing progress.

Hong *et al.* (2004) designed an outsourcing model for the product design and development process. The model employs the knowledge of customer's requirements and knowledge of engineering and manufacturing capabilities (internal and suppliers). According to the model, the performance of product development process is measured in terms of teamwork, development and productivity.

Sabatini (2004) proposed a Virtual IDM Model for Outsourcing Chip Design and Manufacturing. It requires multi-talented, multi-disciplined engineers, having an understanding of a broad range of product development practices, including design-for-market, design-to-cost, design-to-yield, design-for-manufacture, quality control and supply-chain engineering. Having multi-talented staff is the ultimate requirement of small enterprises, because it is not economically feasible for small companies to employ a large number of experts to run their activities. The manufacturing features of the model were useful in designing short-term and long-term outsourcing models for this thesis.

Harland *et al.* (2005) developed an 'assessment framework of the outsourcing risks and benefits for organisations, sectors and nations'. The policy issues are decided by the stakeholders, regulations, technologies and the business Environmental. The framework only focuses on the upper and middle-level management aspects and is restricted to a policy and strategies-development level. The framework resembles a flow chart, providing a sequential process for decision-making and management of the outsourcing.

Hassanain *et al.* (2005) proposed a framework model for outsourcing asset management services that consisted of five sequential processes/stages. The first stage identifies the asset management processes. The core and non-core asset management business activities are identified, followed by evaluation of alternatives to outsourcing. In the next stage outsourcing of asset management services are assessed, by performing identification of outsourcing goals and functions for outsourcing. The following stage involves the development of outsourcing contracts and negotiation of the contracts. In the fourth stage procedures for transfer of asset management functions are established, including plans for

improvements. In the final stage procedures are set out for contract management and evaluation of contracts.

Bragg (2006) structured a totally outsourced manufacturing framework. The framework shows the activities and flow of products amongst the company, customers and supplier (outsourcee). It does not include any other detail.

By adopting outsourcing, organisations have encountered certain problems. These are listed as follows:

Problems due to outsourcing contract: The outsourcing contracts are drawn up before the outsourcing operations are started. After the outsourcing is started, the outsourcer and outsourcee become busy coping with their requirements. According to the literature review, very little attention is paid to the contracts, unless disputes arise. After a while the outsourcing contracts become outdated, because the participants have not considered the need to update them. Service quality may decline throughout the contract (Bahli and Rivard, 2003), but improvement can be achieved using effective Service Level Agreements, and acquiring some technical knowledge of the relevant field. During the literature review, it was noted that in most cases the non-performance penalties and contract length were not addressed in the contract. The contracts were also not flexible to accommodate any changes. The Pricewaterhousecoopers reported that chief information officer does not have the necessary legal and contract managing skills to make sure that the outsourcing contract work well (Nexis, 20.08.2004).

Hidden costs: The manufacturing companies based in developed countries have been outsourcing their manufacturing activities to manufacturing companies based in developing countries, in order to save costs.The labour cost differential between manufacturers and suppliers provided the most obvious advantage to manufacturers who have outsourced. Outsourcing allows reduction in costs in the region of 20% - 40% (Namasivayam, 2004).

In spite of savings, a number of unaccounted, hidden costs were identified in the literature survey. Those were causing outsourcing problems. The hidden costs are vendor search

cost, contracting cost, enforcement cost, cost due to currency fluctuation, customs requirements, staff retraining cost, new software system acquisition cost, transition cost and post-outsourcing cost. Tafti (2005) highlighted the hidden costs of outsourcing (vendor search cost, transition cost, post outsourcing cost), Gonzalez *et al.* (2005) also discussed hidden costs (cost due to dismissing or transferring staff, licence cost, transaction cost, contract cost), and Chan and Kumar (2007) identified insurance costs as hidden costs. Feenstra and Hanson (2004) considered packaging and labelling of the product as hidden costs. Additional transaction costs were due to searching for possible suppliers through the tendering and evaluation process and additional monitoring costs were incurred, as outsourced suppliers require strict monitoring, compared with in-house monitoring. Additional costs due to restructuring, redundancies, labour overtime, foreign exchange cost, additional tax charges and currency exchange rates add to the hidden costs. The costs of natural disasters and pollution, associated with the outsourcing of manufacturing, are also incurred. The increase in costs occurs from unforeseen (hidden) expenses (Bahli and Rivard, 2003). Trent *et al.* (2003) highlighted that the fluctuations in the currency exchange rate also affect the manufacturing cost, due to uncertainty. The changes in customs and tariff rates also influence the cost of manufacturing, and should be considered carefully, otherwise problems can arise. Kulmala *et al.* (2006) identified outsourcing problems due to transactions costs. The transaction costs differ between different governance structures in business relationships, and this represents friction in the market.

Loss of in-house skills and expertise: The growth in electronic content and in specialist material supply has already transferred expertise to suppliers that manufacturers would find difficult to replicate, especially since some of the suppliers concerned are able to transfer technology from other fields to automotive technology in a way not accessible to vehicle manufacturers. The careful selection of the participant with cutting-edge technologies and skills can provide access to the right capabilities and resources (Namasivayam, 2004). The outsourcing often involves transfer of human resources that results in a reduction in the internal expertise of the company (Earl, 1996). The company should evaluate all staff before transition and identify those who need to be retained or transferred.

Loss of in-house knowledge and information: Outsourcing is the exploitation of available resources. The outsourcer and outsourcee could improve their processes by sharing knowledge and information of their experiences. When companies are not outsourcing, creativity and innovation depends upon their individual investments and the expertise of their workforce. The companies may not have resources or capability for creativity and innovation. By means of outsourcing, companies can complement each other's capabilities and improve the process by sharing creativity and innovation. Hoecht *et al*. (2006) argued that outsourcing has little protection against the loss of competitive knowledge advantage to the industry and competitors. The loss of in-house knowledge due to outsourcing is one of the most commonly-cited problems that raise the level of dependence on external suppliers (outsourcees).

Unsuitable supplier: In a research study, Bragg (2006) stated that the supplier may not be able to manufacture in time to meet on-time delivery. The author identified that the supplier (outsourcee) could not deliver on time because of dedication to other customers (companies). The other companies (outsourcers) were given the highest priority. There is also a possibility that the supplier (outsourcee) may not have the capability to manufacture the products on time. Webb (2004) reported that there was a lack of consistency and reliability when parts are outsourced for manufacturing, which resulted in poor quality. It has also been mentioned that outsourcee companies do not have the capability to process certain quality materials required, due to the lack of relevant technology. Webb (2007b) identified that outsourcing parts manufacturing to China required bringing the company up to international standards.

Delay in delivery: The ultimate objective of a manufacturing company is to meet market demand. When there is a dynamic fluctuation in the demand, and the manufacturing company is unable to meet the demand on its own, there is a possibility that the market could be stolen by a competitor. Therefore, by selecting the right manufacturing supplier, the manufacturing companies can reduce the lead time and speed up the delivery process. A delay in delivery can be due to a number of factors such as error in order request, incomplete delivery (order size/quantity), mistake or error in delivery destination, errors in delivery note or incorrect delivery note, and errors or mistakes in invoices.

Quality problems: Manufacturers are outsourcing to enhance the quality of their products, because the quality of the product very much depends upon manufacturing technology, machine tools (manufacturing machinery) and manufacturing expertise (capable staff). The manufacturing companies find it difficult to procure the latest equipment, acquire the right technology and train staff in order to achieve the required quality. Bambrough (2005) mentioned that reduced cost was achieved at the cost of a lower-quality service model. Bollen (2004) stated that Prudential (Predential Insurance) needs investing in India, for training to improve quality. Dwayne (2004) mentioned that the reason for outsourcing failure is due to a lack of service and relationships that result in lack of timeliness, low reliability and high performance loss; whereas Cole-Gomolski (1999) reported a decline in quality of outsourcing service, and Gibson (1998) fears that outsourcing is unable to attain world-class quality.

Lack of management and monitoring capability: The manufacturing companies outsource their manufacturing operations to specialist suppliers in order to improve their business performance. For example, the manufacturers have been allocating increasing proportions of their investment in new production capacity in China and other growth markets; they can less easily afford and maintain in-house capacity that may be replaced by, or even sold to the supplier. There were a large number of management issues identified in the literature survey which had been causing problems in outsourcing operations. Kremic *et al.* (2006) blamed lack of methodology and skills within organisations for managing and monitoring outsourced functions, for outsourcing failure. There were other factors responsible for outsourcing problems such as: the lack of a sophisticated level of strategy, worldwide information level about manufacturing and trade, personnel lack of advanced knowledge and skill, lack of extensive coordinated and communication mechanisms, lack of organisational structure to centrally coordinated global activities and lack of executive that endorses a global approach to sourcing.

Lack of advance communication system: According to the literature survey, Razzaque *et al.* (1998) identified that lack of advance information technology that links manufacturing suppliers, freight companies, warehouse and storage providers and the company, was responsible for outsourcing problems.

Human resources: During the literature survey a number of human resource issues were identified, contributing to outsourcing defects. These issues were poor morale of employees, skills erosion of employees, false sense of responsibility, dissatisfaction and loss of key employees.

Lack of understanding of participant's objectives: Rebernik *et al.* (2006) pointed out that the most significant obstacles that prevent an efficient outsourcing arrangement are misunderstanding of the client's objectives, policies and culture, or the client disagrees with the provider's objectives and policies. Bragg (2006) highlighted that the supplier may not be able to understand the business requirements of the company (outsourcer) due to distance in location.

A set of common problems were identified through literature survey, case studies and discussions/interviews with the managers of outsourcing companies. It was found out that most of the problems were caused by insufficient detailed analysis of market criteria, empirical suppliers selection, inadequate agreements / contracts, less comprehensive short- and long-term planning, lack of assessment tools/methodology for the outsourcing performance (on short and long term) and non-synchronization between the management of the outsourcer and outsourcee towards the common goal of streamlining the future collaboration.

1.3 DEFINITION OF PROBLEM

By following the footsteps of IT, services and BPO, the manufacturers also have started practicing outsourcing to enhance their competence but are failing to achieve the objectives. The offshoring Craze (2005) highlighted that outsourcing has happened in countries that have offered cheap labour and materials for many years. The simple reason for outsourcing to India, China and East European countries is the cost. Though organisations practising outsourcing have an advantage over the non-practicing due to cost but soon many will join the race that may cause the organisations practicing outsourcing to lose comparative advantage.

The author criticised as many executives and analysts fear that many firms are jumping in by the promise of the cheap labour without thinking things through. Very soon due to hidden costs, ineffective management and lack of secure communication, the potential benefits of the outsourcing are often lost. Jiang (2006) reported that the outsourcing outcomes had failed to meet expectations.

Critical analysis shows that the present models and frameworks are lacking methodologies to identify suitable suppliers, supplier selection criteria and suggest drawing of a complete detailed contract. In conclusion, the research problem is to identify causes those inhibit the success of outsourcing operations and develop suitable decision models.

1.4 RESEARCH QUESTIONS AND HYPOTHESIS

By carrying out this research, it is attempted to answer the following research questions.

- The study of the existing decision models and frameworks used within companies practicing outsourcing and how they differ from each other in performance and effectiveness.
- The suitable supplier selection criteria and supplier selection models for small and medium sized outsourcing manufacturing companies.
- Guidelines for developing and implementing outsourcing contract.

By carrying out literature review the following hypotheses have been developed.

Hypothesis 1: The most suitable supplier could only be selected if the supplier selection criteria are identified with the help of experienced company managers.

Hypothesis 2: The failure in outsourcing operations could only be avoided by implementing decision models which are developed using the information acquired from relevant companies.

Hypothesis 3: The outsourcing decision models which are developed without adequate information from relevant companies may not contribute significant improvement.

The answer to the above research questions and the validation of the hypotheses is considered as contribution to the knowledge.

1.5 THE AIMS AND OBJECTIVES

Having identified the problems of the current outsourcing models, the aim of this research is to address them by designing appropriate solutions for small and medium sized manufacturing companies. Therefore the following objectives were defined in this thesis:

1. Identification of outsourcer's criteria for outsourcee selection in small and medium sized manufacturing companies
2. Formulation and application of a model for numerical evaluation of outsourcer's criteria for outsourcee selection
3. Formulation and application of a model for outsourcee (supplier) selection
4. Formulation of a model for drawing up a Manufacturing Level Agreement

1.6 OUTLINE OF THE THESIS

The contents of the thesis were organised in the following format:

Chapter 2 Methdology	The methodology used in achieving objectives has been explained. It includes details of the research design, methods used for data collections, data analysis strategies and model construction are presented.
Chapter 3 Questionnaire Design	Guidelines are provided for the construction of a questionnaire, in order to acquire information from manufacturing companies which are outsourcing. The chapter includes the designing of two questionnaires. The first questionnaire is designed for enquiring about the defects in the outsourcing of manufacturing activities, application of manufacturing and management tools, education and training programmes and finaly outsourcee selection criteria.

	The second questionnaire is designed for acquiring information about the relative importance (priorties) of supplier selection criteria.
Chapter 4 Outsourcee (Supplier) Selection Criteria	Provides detailed analysis of supplier (outsourcee) selection criteria for small and medium sized manufacturing companies. It began with a review of criteria used in previously published literature. Next, the information was collected from small and medium sized manufacturing companies using a questionnaire. Finally, with the help of managers, a set of eight outsourcee selection criteria with twenty-six sub-criteria were finalised for a satisfactory supplier selection model for small and medium sized companies.
Chapter 5 Numerical Evaluation of Outsourcer's Selection Criteria	Application of the conversion model which maps subjective opinions of the surveyed elements into objective ranking for numerical evaluation of outsourcer's criteria for outsourcee selection in small and medium sized manufacturing companies. The model is formulated using analytical hierarchy process and cluster analysis to show how raw data should be transformed into matrices and surveyed Eigenvectors. The result is an Eigenvector that is representative for the entire range of companies surveyed. The elements of the Eigenvector represent the relative priority weights of surveyed companies.
Chapter 6 Selection of Outsourcee (Supplier): A Case Study of Totalli SRL	Presents the application of the outsourcee selection model on Totalli SRL (European-based manufacturing company established in 2004) as a case study for selection of a suitable outsourcee. The model comprises the Analytical Hierarchy Process (AHP), Cluster Analysis (CA) and criteria scoring of outsourcee. The priorities (importance weights) of each criterion/sub-criterion are then multiplied with corresponding ranking score values and the resultants are summed to a final score. The outsourcee that

	achieves the highest total score in the model may be considered the most suitable.
Chapter 7 Development of Manufacturing Level Agreement for Outsourcing	Introduces how to draw up and implement a manufacturing level agreement (contract) for outsourcing of manufacturing operations. All stages of the outsourcing are included, starting from the first transaction to the end of the specified contract period, and even in the event of early termination of the contract due to unforeseen circumstances.
Chapter 8 Conclusions	This chapter presents the overall conclusions of the work.
Chapter 9 Recommendations for Further Work	This chapter proposes the possibilities of further developments.

Chapter 2

METHODOLOGY

2.1 INTRODUCTION

This chapter describes the methodology that is used in achieving objectives set to carry out the research. Research methodology includes details of the research design, research methods used for selecting the population, sampling procedure and data analysis strategies and the work programmes used in this study are presented.

2.2 RESEARCH METHODOLOGY

In order to carry out the research, a specific methodology suitable for small and medium sized companies was selected. Prior to that analysed methodologies adopted by other researchers by carrying out literature survey. For example, Johnson (2002) used deductive methodology to carry out an empirical study of second-tier automotive suppliers. Sykes *et al.* (1997) used inductive methodology to study the effect of training and empowerment in improving the performance of an optical fibre manufacturer in the north of England, which had recently been taken over by a European company. Initially, data were collected from the literature survey, and then from the company documents. Then a questionnaire was structured for conducting interviews. The interviews were designed to extract the information required to meet the objectives of the research.

Other authors such as de Boer *et al.* (2006) applied inductive methodology for developing a conceptual decision model for outsourcing of logistics activities. In their research, case studies enabled them to achieve the required depth in describing the decision-making process. A number of interviews were conducted to identify and select suitable logistics activities and establish the influence of the supply market. The findings of the interviews were analysed, using an existing prescriptive model followed by decision-making routines.

From the point of view of the type of data processed, the research methodology can be classified as qualitative or quantitative. The qualitative research methodology was

developed by scientists to deal with non-numerical data collection, such as written or spoken words. Examples of qualitative data sources include documents, texts, interviews, questionnaires and observations. McIvor *et al.* (2009) applied the qualitative methodology approach to assess the applicability of a number of performance management techniques in the outsourcing process. The quantitative research methodology deals with numerical data. It is mainly used by engineers, statisticians and mathematicians.

The information gathered from the analysis was used in designing the research methodology for small and medium sized manufacturing companies. Figure 2.1 illustrates the current research methodology in the form of a flow chart.

The research methodology starts with data acquisition, followed by data analysis and designing of models and frameworks. Once a model is designed, it has to be tested and eventually improved upon.

In the first stage of the methodology, the research objectives were defined after carrying out a literature survey. In the next stage data were collected relevant to outsourcing. Data are classified mainly into two types; primary data and secondary data. The primary data refers to that which is collected first time and used specifically for the current research. The primary data were collected by means of questionnaires, interviews and case studies. The secondary data refers to that which was compiled previously for other purposes, rather than the current research. In order to maximise the coverage of the research topic, both secondary and primary data were collected. The secondary data were collected from a number of sources, such as academic journals, conference papers, published articles from newspapers, reports from Institutes of National Statistics and case studies from published literature.

In the following mentioned flow chart, the secondary data were collected through a literature survey and the primary data were collected using questionnaires, interviews and case studies from the experts/decision-makers of the manufacturing companies practising outsourcing.

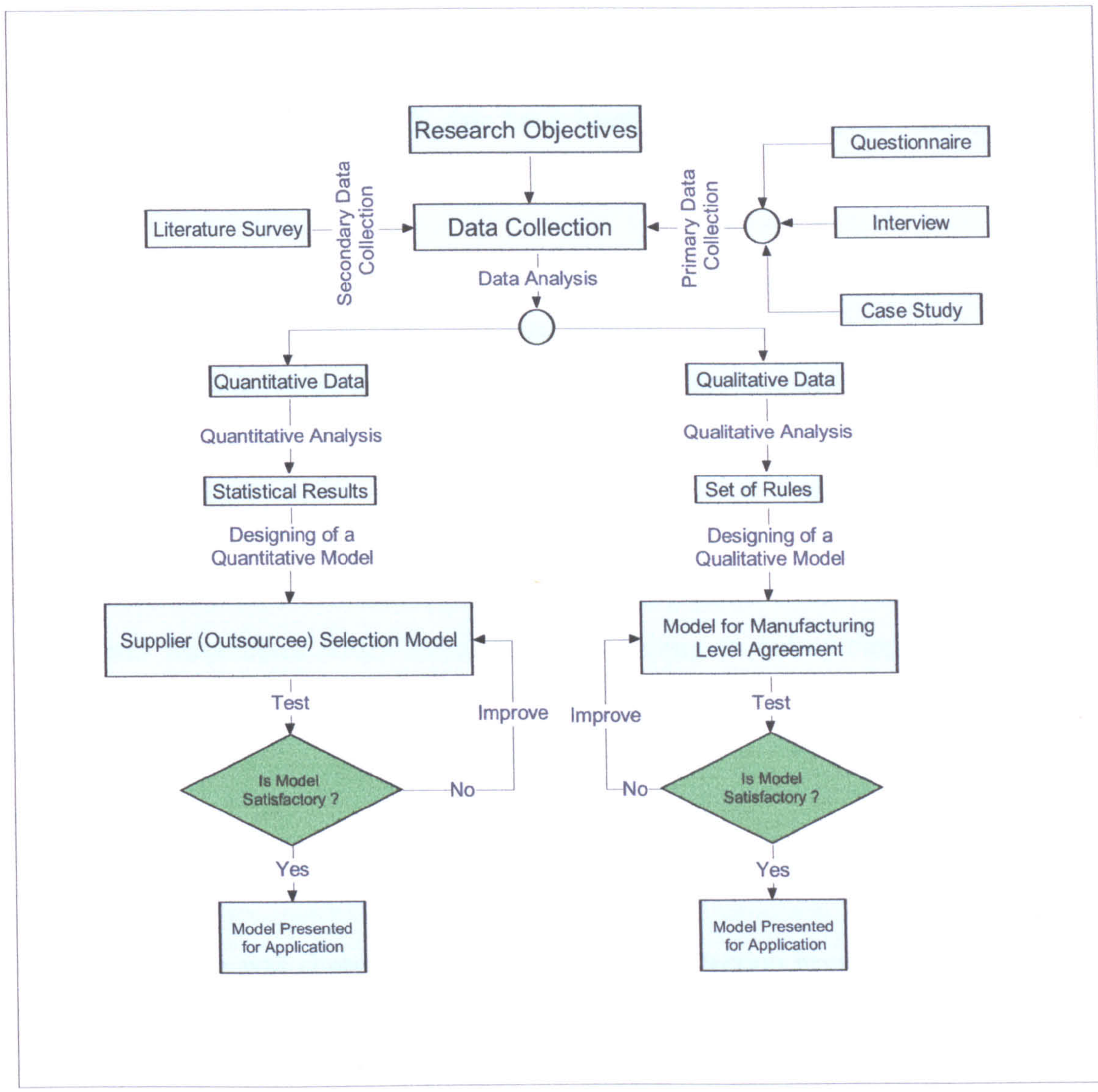

Figure 2.1: Outsourcing Research Methodology Flow Chart

In the following stage, the collected data were analysed and sorted into statistical results and a set of rules. The statistical results consisted of quantitative data and the set of rules consisted of qualitative data.

In the next stage, the statistical results were used for designing a quantitative outsourcee selection model. The set of rules was used for designing a qualitative model for developing and implementing manufacturing level agreement. Each model was tested in the next stage. If the model was not satisfactory, it was redesigned; otherwise it was presented to the company for application or feedback.

2.2.1 Data Collection

In order to carry out this research, data have been collected through a literature survey, questionnaires and interviews.

The research was started by reviewing published literature on outsourcing and areas of study surrounding the outsourcing. For this purpose, a number of information and data collection sources were used: the National Statistical Survey, institutional records, text books, journals, conferences papers and newspapers and Athens databases.

The outsourcing models, frameworks and strategies employed by most of the outsourcing enterprises were selected for investigation. The investigation was carried out to identify the defects and weaknesses which have been contributing to outsourcing failure, supplier selection criteria used in various supplier selection models and outsourcing assessment methods. The investigation also identified the outsourcing areas where only a limited amount of research had been carried out, such as outsourcing of manufacturing for small and medium sized companies.

The questionnaire was chosen as a method for data collection because it was considered the quickest in collecting information within a short time (Yorke, 1995). A questionnaire allows the respondents to answer the questions accurately, without distraction. Previously, the questionnaire was used for surveying global outsourcing strategy, as shown by Elmuti and Kathawala (2000). Another way for using the questionnaire in this research was based on Dewettinck and Buyens (2002) work, involving a questionnaire comprised of open-ended questions as a guideline to grasp the specificity of each case. Therefore, it was decided to use a questionnaire for primary data collection. It was ensured that the relevant managers responded. The covering letter clearly stated the purpose of the questionnaire as suggested by Dean and Kiu (2002).

Most of the information collected from the literature review was related to outsourcing of IT, services sector and business process outsourcing. Very limited research was available on outsourcing of manufacturing activities. Since there is a significant operational difference amongst manufacturing organisations, information technology companies,

service industries and any other outsourcing sector, it was necessary to acquire information from a relatively large number of manufacturing companies for empirical generalisation. In order to carry out current research, two questionnaires were prepared and approved by the ethics committee.

The first questionnaire was designed to carry out empirical investigation into the defects/weaknesses of outsourcing operations, and outsourcee selection criteria in the manufacturing sector. There were five important elements selected in designing the questionnaire: the outsourcing system and its elements, manufacturing and management tools, manufacturing technologies and techniques, inputs and outputs of the questionnaire and external influencing elements.

For ease of understanding, the questionnaire was divided into five parts. Part 1 of the questionnaire comprised thirty-five questions. The questions were designed for acquiring information about defects in outsourcing of manufacturing activities. Part 2 of the questionnaire was composed of sixteen questions, which were related to management and manufacturing tools. Part 3 of the questionnaire comprised questions which were relevant to modern technologies and techniques. Part 4 of the questionnaire comprised five questions, which were designed for assessing the educational and training activities of an organisation. Part 5 of the questionnaire was an open-ended section that requested respondents to select outsourcee selection criteria from a given list, or suggest their own.

The second questionnaire was designed for finding out the relative-importance weights of supplier selection criteria. Eight main criteria and twenty-six sub-criteria were used in designing the questionnaire. The second questionnaire consisted of nine parts. Part 1 was structured from eight main supplier selection criteria. Parts 2 to 9 of the second questionnaire were structured from sub-criteria of the main criteria.

In order to get the answers to the questionnaires, it was ensured that the respondents understood the questions and the essence of the whole study by first giving the respondents a brief background to the study. In order to maximise the reply response of the questionnaire, both postal and e-mail means were used. Follow-on telephone calls were made and reminder e-mails were sent. The best responses were received where personal

visits were made to the companies, and the questionnaires were explained and filled in at the same time.

For a better understanding of outsourcing operations of manufacturing activities, a number of semi-structured and formal interviews were conducted with managers of the manufacturing companies.Chetty and Cambell-Hunt (2003) used semi-structured interviews as the main form of data gathering, to carry out research on internationalisation among small and medium sized firms. McIvor *et al.* (2009) also used semi-structured interviews for data collection to assess the applicability of a number of performance management techniques in the outsourcing process.

The main reason for employing the interview technique was the need for a very quick and personal method of collecting in-depth data. There was a chance to discover new data and the questions could be repeated for the respondents, to enhance understanding. This helped to provide a more comprehensive view of outsourcing of manufacturing issues.

The interview with each respondent lasted for approximately an hour. The respondents were asked about outsourcee selection criteria for small and medium sized manufacturing companies from a proposed list, and from their own points of view. The respondents were asked, using an open-ended question, about the problems they faced in their outsourcing operations. The most important question asked of the respondents during the interviews, was how outsourcing of manufacturing decisions should be made.

Each company was visited a number of times. The respondents were asked the same questions without any sequence, so that systematic generalisation of the responses could be avoided. This helped to provide a more detailed view of outsourcing of manufacturing issues.

The case study was used to identify the outsourcing of manufacturing in its uniqueness, because it required a narrative approach rather than one framed in terms of variable analysis.

In this research, two companies were selected for case studies: Newton Equipment and Totalli SRL. Case study refers to research that investigates few cases, often just one, in considerable depth. "*The aim of the case study research is to capture cases in their uniqueness, rather than to use them as a basis for wider generalisation, or for theoretical inference of some kind*" (Yin, 1994). This often requires a narrative approach, rather than one framed in terms of variable analysis. Case study is an 'empirical enquiry' that investigates a contemporary phenomenon within some real-life context as stated by Barnes (2001) and Yin (1994). Case study is also described by Gomm *et al.* (2000) as a specific form of inquiry, one which contrasts with two other influential kinds of social research, experiment and social survey. Case studies enabled de Boer *et al.* (2006) to achieve the required depth in describing the actual decision-making process.

Lau and Zhang (2006) used case study to gain an insight into the real motives behind the companies engaged in outsourcing, the obstacles and problems in the outsourcing process, and their impact on the organisation's performance. Chetty and Cambell-Hunt (2003) used a multiple-case approach and Eisenhardt (1989) recommended between four and ten case studies for theory generation. The case studies often required a narrative approach rather than one framed in terms of variable analysis.

Online survey is a relatively new way of acquiring information. A number of online survey services are available; some of them are free for a limited trial period. The survey services also provide an option in designing a suitable survey tool. The data collected using online surveys can be stored either online, or using an appropriate storage device. However, due to the scope of this research and time limitations, the online survey was not considered necessary.

2.2.2 DATA ANALYSIS

The collected data comprise both qualitative and quantitative types. The qualitative data were analysed using the five-stage process: familiarisation, identification, indexing, charting and mapping and interpretation.

The quantitative data were analysed using Excel and Statistical Package for Social Scientist (SPSS).

The information collected from the literature review, questionnaire survey and interviews was analysed to identify the constraints and problems that need to be addressed for improving outsourcing operations. Some of the constraints identified are 'maximum quantity of raw material available', 'exclusive products' (the products which cannot be manufactured in more than a certain quantity), 'maximum number of machine hours available' and 'capability to process a material'. Some of the problems identified are 'variation in cost', 'hidden costs', 'unable to deliver on time' and 'poor quality'.

As a result of data analysis, the outsourcee selection criteria were also finalised, such as cost, quality, on-time delivery and reputation.

2.2.3 MODEL DESIGN

The outsourcing model is a set of schematic instructions for performing outsourcing activities. The results of the data analysis were used to design outsourcing models for small and medium sized manufacturing companies: model for selecting a supplier (outsourcee) and model for guidelines to draw up manufacturing level agreements.

The model for selecting a supplier (outsourcee) was presented for testing to the management of Totalli SRL. The results of the model were in agreement with the decision previously made by the company for selecting a supplier.

The the model for guidelines to draw up manufacturing level agreements were presented to the managing director of Newton Equipment. The managing director has been providing feedback in part because of the large size of the model. Therefore, the model has been updated continuously, according to the feedback.

2.3 CONCLUSIONS

The selected methodology is a standard approach based on defining the problem, followed by solving the problem with a suitable applicable solution followed by improvement. It resembles the scientific methods of developing a hypothesis; test the hypothesis through some experiments, if the experiment validates the hypothesis then the hypothesis becomes a formula, otherwise the hypothesis is modified and retested until proves correct.

Following the same approach, a number of models were constructed layer by layer based on the information collected from literature survey, questionnaires and interviews. The models were presented to the managers of the companies for feedbacks and were updated according to feedback.

Chapter 3

QUESTIONNAIRE DESIGN

3.1 INTRODUCTION

In this chapter all important factors are analysed in designing a questionnaire, ranging from the language of the questionnaire to cultural issues. The chapter also includes the construction of two questionnaires for acquiring information from small and medium sized manufacturing companies which are practising outsourcing. The first questionnaire is designed with the rationale for enquiring about the frequency of defects in the outsourcing of manufacturing activities, usage of manufacturing and management tools and finaly outsourcee selection criteria. The second questionnaire is designed for acquiring information about the relative importance (priorties) of supplier selection criteria. This chapter also highlights the questionnaire validation process.

3.2 PURPOSE OF QUESTIONNAIRE

Synodinos (2002) proposed that the purpose of the questionnaire is gathering data that evaluates quality, to drive and measure change. The questionnaire should have the pragmatic capacity to gather information relatively quickly, which can then be used as a basis for the contribution of critical self-scrutiny (Yorke, 1995).

Most of the information collected from the literature review is related to the outsourcing of information systems and technology. A very limited amount of research material was available on the outsourcing of manufacturing activities.

There is a significant operational difference amongst manufacturing organisations, information technology companies, service industries and any other outsourcing sector. Therefore, it was essential to collect data from manufacturing companies practising outsourcing. There was a need for finding a suitable method in order to collect information

from manufacturing companies involved in outsourcing. There were three possible methods considered for data collection: questionnaires, interviews and case studies. Each had its advantages and disadvantages. Table 3.1 illustrates the differences among interview, case study and questionnaire.

Interviews	Case Study	Questionnaire
Acquiring information from a relatively small number of cases (organisations)	Acquiring information from a relatively small number of cases (organisations) (sometimes just one)	Acquiring information from a relatively large number of cases (organisations)
Information is gathered and analysed regarding a small number of features of each case.	Information is gathered and analysed with regard to a large number of features of each case.	Information is gathered and analysed regarding a small number of features of each case.
Face-to-face interaction with respondent	Face-to-face interaction with respondent is not necessary.	There is no need for face-to-face interaction with respondents.
The main aim is to fully understand the interviews, with no interest in theoretical inference or empirical generalisation.	The main aim is to fully understand the case, with no interest in theoretical inference or empirical generalisation.	The aim is empirical generalisation, from a sample to a finite population, though this is sometimes seen as a platform for theoretical inference.

Table 3.1: A Comparison of Interview, Case Study and Questionnaire

For empirical generalisation, information from a relatively large number of small and medium sized manufacturing companies was required. Therefore, it was decided to use questionnaires for preliminary data collection. The first questionnaire was designed to carry out empirical investigation into defects/weaknesses of outsourcing operations, management and manufacturing tools and supplier selection criteria used in the manufacturing sector. The second questionnaire was designed for acquiring information about relative importance weights of supplier selection criteria. The overall aim of the questionnaire-based investigation was to identify weaknesses/defects and supplier selection criteria for developing outsourcing decision models.

3.3 QUESTIONNAIRE DESIGN PROCESS

A questionnaire is an instrument of research, as well as a tool for data collection. Its function is to measure precisely and logically, to achieve an overall research plan and to identify objectives (Oppenheim, 1992). Sapsford (1999) explains that a questionnaire is a set of systematic questions which the researcher wishes to have answered. Robson (2002) explains that a survey questionnaire is carried out as part of non-experimental fixed design.

The questionnaire construction process is divided into three parts. In part one the purpose of the questionnaire is described, as is shown in Figure 3.1

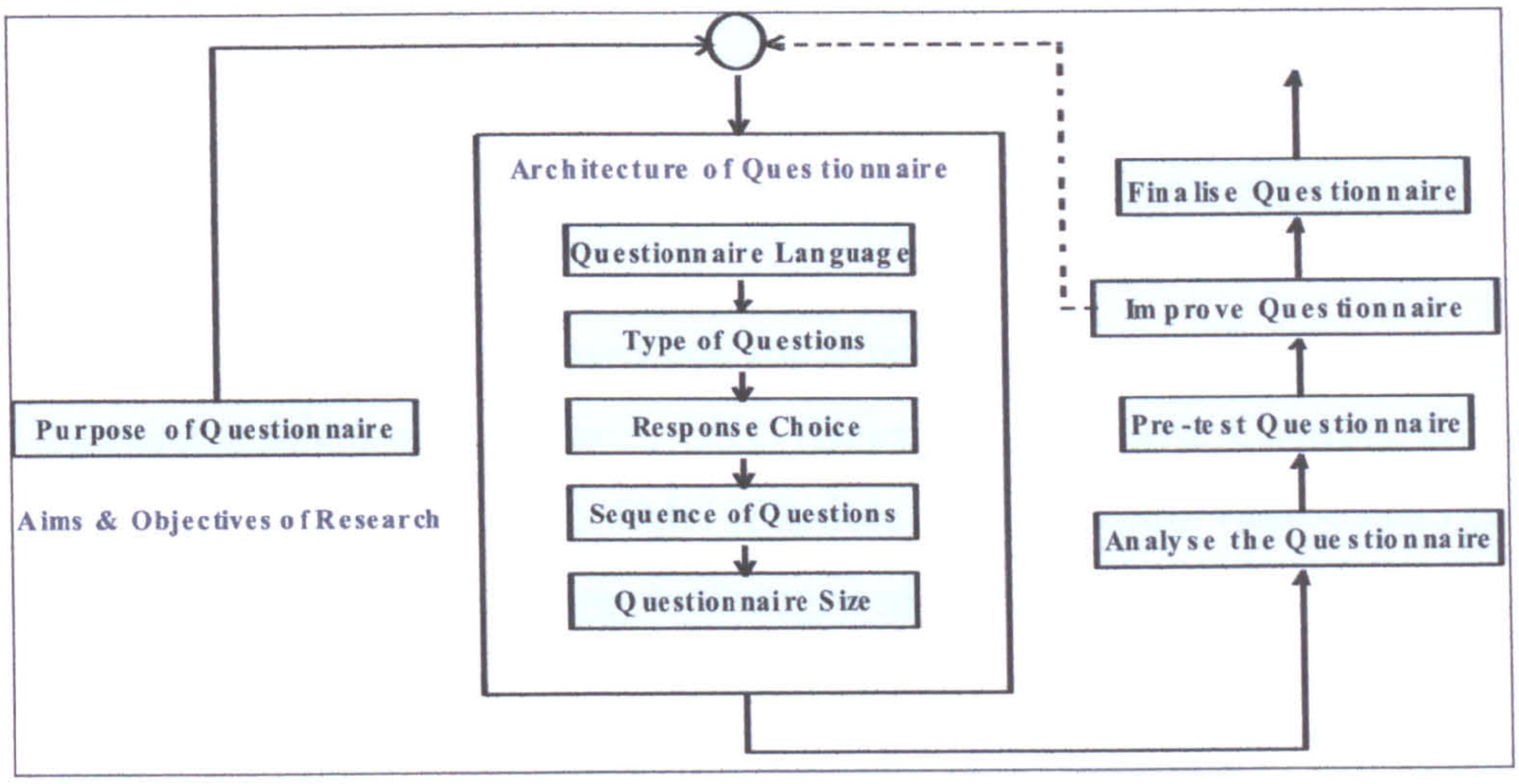

Figure 3.1: Questionnaire Construction Process

Part two describes the architecture of a questionnaire, such as 'type of questions', 'sequence of questions', 'response choice' and 'questionnaire size', which are explained in the following sections. The third part consists of analysis, testing, validation and improvement of the questionnaire.

3.4 DESIGN OF FIRST QUESTIONNAIRE

There are five important elements selected in designing the first questionnaire. These are the outsourcing system and its elements, manufacturing and management tools, manufacturing technologies and techniques, inputs and outputs of the questionnaire and external influencing elements. The outsourcing elements used in questionnaire construction are described as follows.

3.4.1 MANUFACTURING AND MANAGEMENT TOOLS

The most commonly used manufacturing and management tools such as TQM (Total Quality Management), TQC (Total Quality Control), Zero defect programmes, Kaizen,

ISO 9000/BS 5750, Pull System, SPC (Statistical Process Control), Plant within Plant, Cellular Layout, TPM (Total Preventive Maintenance), LM (Lean Manufacturing), Benchmarking, Employee organised its Team, In-house training Programme and Job rotation, are used in the questionnaire design.

3.4.2 MANUFACTURING TECHNOLOGIES AND TECHNIQUES

Manufacturing technologies, techniques and machine tools such as NC (Numeric Control), CNC (Computerised Numeric Control), DNC (Distributed Numeric Control), GT (Group Technology), IR (Industrial Robots), FMC (Flexible Manufacturing Cells), FMS (Flexible Manufacturing Systems), CIM (Computer Integrated Manufacturing), AS/AR (Automated Storage and Retrieval), AMH (Automated Material Handling), ADS (Automated Delivery System), MRP (Material Requirement Planning) and MRP II (Material Requirement Planning II), are included in the questionnaire design. The manufacturing technologies and techniques are divided into essentials and desirables. For example, CNC machines are essential for manufacturing and Automated Storage and Retrieval units are desirables.

3.4.3 EXTERNAL ELEMENTS

The outsourcing operations are affected by external influencing elements. Therefore, the external elements, such as competitors, availability of suppliers, ecological elements, political elements, environmental elements and social elements were taken into account in order to design the questionnaire.

3.4.4 COST, DELIVERY AND QUALITY

Cost, delivery (delivery on time) and quality, and their components, are selected as important factors in order to design the questionnaire. Cost, delivery and quality are also considered essential for assessing outsourcing operations.

3.5 DESIGN OF SECOND QUESTIONNAIRE

The second questionnaire is designed for finding out the relative importance weights of supplier selection criteria. There are eight main criteria and twenty-six sub-criteria used in designing the questionnaire. The identification process and detail of supplier selection criteria and sub – criteria is explained in chapter 4.

3.6 QUESTIONNAIRE MANAGEMENT

Synodinos (2002) suggested that there is no method superior to others under all circumstances. A number of factors, such as aims, objectives and rationales which motivated questionnaire formulation, target groups, geographic distribution and available resources, were considered in the selection of the appropriate questionnaire-management mode. Cost was one of the most important determinants in questionnaire management. Cost of questionnaire management included preparation cost of questionnaire, postal cost of questionnaire (postage, fax and e-mail communication), storage cost of questionnaire data, data processing cost and cost of hardware/software. Due to the advancement in technology, e-mail is considered the least costly and most appropriate medium for questionnaire management. The questionnaire is e-mailed to the manufacturing companies. Search engines 'Kampass' and 'Fame' are selected. In order to simplify and minimise the time and effort imposed on the organisations being investigated, very clear questionnaire-specific instructions were provided. Finally, in order to clarify the context of the questionnaire, the essence of the whole study was concisely explained in a covering letter preceding the questionnaire.

3.7 RESPONSE CHOICE FOR THE QUESTIONNAIRE

While designing the questionnaire, extensive search is carried out on the response choices and also the art of configuring the questionnaire.

The first questionnaire is structured using close-ended questions (fixed response questionnaire). The close-ended questions are found relatively less complicated to code and

analyse. It is ensured that all possible response options are covered without overlapping, and without overwhelming the respondents with too many alternatives. Some of the substantive choices consisted of value ranges. The response alternatives are determined by the questionnaire administration method and the question types. Part 1 of the questionnaire comprised thirty-five questions. Fifteen of these questions have a Boolean response choice (Yes/No), five questions have a response choice of three options, fourteen questions have a response choice of four possible answers, and finally one question has a response choice base on the Likert scale of five. The questions of Part 2 are designed with a response choice of four options similar to the Likert scale, and the respondents are advised to enter '?' in the case of being unsure about the choice. Part 3 of the questionnaire has a response choice of 'tick' or 'leave blank', and in case of 'not sure' enter '?'. Similarly, the first four questions of part 4 of the questionnaire have a response choice of 'tick'. The last question is designed to enquire about the duration of the training period, by selecting one of five given choices.The part 5 of the questionnaire have a response choice to 'tick' or the respondent can propose its own suggestion.

The second questionnaire is structured in order to compare criteria/sub-criteria. The comparison is carried out on a Likert scale of nine (1 for equally preferable and 9 for extremely preferable). The questionnaire consists of three columns and $\frac{n(n-1)}{2}$ number of rows[$n = Number\ of\ criteria\ or\ sub-criteria$]. The first and the third columns are listed with the criteria/sub-criteria required to be compared. The middle column is left blank, to be filled in by the respondents.

3.8 SEQUENCE OF THE QUESTIONS

In the first questionnaire, in order to eliminate confusion, the complex issues are broken down into simple scenarios. Then single questions are used for assessing the issue. The questions are sequenced very carefully and in this regard flow charts are used. The questionnaire consists of three parts: 'introduction', 'main body' and 'characteristics of respondents/organisations'. The introduction provided a brief description of the study. Screening questions are also included at the end of the introduction to select the respondents who satisfy the selection criteria. Alternatively, this is included in the covering letter. The

main body of the questionnaire contains topical questions. The questions are arranged logically and asked in a non-threatening manner. The questions related to similar topics are grouped together and ordered from the general to the specific. The last section is related to respondent/organisational characteristics. The questions are designed in such a way that they are applicable to most of the manufacturing organisations.

The first section of the questionnaire commences by enquiring whether the organisation is outsourcing part, or all of its manufacturing activities. It also asks about the organisation's preferences regarding cost, on-time delivery and quality of the outsourced products. The next set of questions investigates the reasons for delay in the processing of the order, and the factors which are responsible for the delay. The following set of questions is designed for identifying the causes of the delay, in percentages. These causes may range from communication errors to incorrect invoice matching. The next set of questions is formulated, in order to establish the ownership of the technology and patents involved in the manufacturing of outsourced components. One of the questions is designed in an intrusive way, enquiring whether the despatch of defective components is deliberate, because the intentions of the supplier are completing the order without caring about the consequences. The next set of questions is designed to find the causes of commercially-sensitive information leakage, and the suspects involved in giving away classified information.

The second section of questions is designed for finding out the extent (Likert Scale of four) to which the outsourcing participants are using manufacturing and management tools. The third section of the questionnaire is designed for assessing the technological capability and techniques applied in processing, that indirectly translates the quality of the outsourcing operations. The fourth section of the questionnaire is designed to find out about the education and training programmes, and to find out whether the participants are involved in personnel development. The fifth section of the questionnaire is an open-ended question that requests respondents to select outsourcee selection criteria from a given list, or suggest their own.

The second questionnaire is also designed, in order to gather responses in an unbiased manner. The second questionnaire consists of nine parts. Part one is structured from eight

main supplier selection criteria. Parts two to nine of the second questionnaire are structured from sub-criteria of the main criteria.

3.9 STRUCTURE OF THE FIRST QUESTIONNAIRE

The first questionnaire is designed to gather responses in an unbiased manner. The questionnaire comprises five parts. Part 1 of the questionnaire comprises thirty-five questions. The questions are designed for acquiring information about defects in the outsourcing of manufacturing activities. Part 2 of the questionnaire is composed of sixteen questions, which are related to management and manufacturing tools. Similarly, Part 3 of the questionnaire is composed of questions which are relevant to modern technologies and techniques. Part 4 of the questionnaire comprises five questions, which are designed for assessing the educational and training activities of an organisation. Part 5 of the questionnaire is an open-ended question that requests respondents to select outsourcee selection criteria from a given list, or suggest their own. A detailed explanation of each part of the questionnaire is given as follows.

Part1. Defects and Weaknesses: Question 1 is structured in order to find out whether the company had been outsourcing part, or all of its manufacturing activities to external management. Question 2 is designed for enquiring about relative importance weights of cost, delivery and quality. The Likert scale of 1 to 5 is used for obtaining responses from respondents. It might be possible that the companies which have assigned higher priority to cost might not expect to receive good quality products and on-time delivery.

Question 3 is designed for enquiring about the perspective of the company, regarding order production delay from the supplier. The first two parts are designed in order to find out whether the company believed that the supplier is committed, or just trying to complete the order in its spare time, if available. The third and fourth parts of the question are designed in order to find out whether the supplier has the capacity or capability for delivering the required order on time. Question 4 is designed for enquiring about specific delays in terms of time units. The delivery system always had been one of the important components of the outsourcing system, and has been responsible for transporting materials and components between suppliers (outsourcee) and the company (outsourcer).

The purpose of questions 5 to 12 is carrying out classification of the defects into sub-categories. Question 5 is designed in order to enquire about the delay in delivery (percentage time), due to weaknesses in the delivery system. Question 6 is designed about suppliers, but asked from the company, in order to find out the percentage delay in supplying orders. It might be possible that the order is ready, but due to certain reasons the supplier is unable to despatch. For instance, the company prepares an order request and sends it to the supplier for manufacturing by a set date. Later, a mistake is identified in the order request, which is corrected. The errors cost resources and results in delays. Question 7 is designed, in order to collect information regarding delay in supplying orders, due to incomplete specifications in order requests. Question 8 is designed for collecting information regarding delay in supplying, or requesting orders, due to incorrect information on order requests. Question 9 is designed, in order to collect information in respect of supplying or requesting orders, due to error in invoicing. Question 10 is designed in order to find out about the delay in order, due to incomplete deliveries. There is a chance that the delivery is despatched to the wrong destination, or to the wrong person. Question 11 is designed for collecting information regarding delay, due to error in delivery destination/location. Question 12 is designed in order to find out the delay, due to error, in not delivering to the right person.

Questions 14 to 17 are designed, in order to find out the need for modernisation of the delivery system. Question 14 is designed, in order to enquire about the variations in the order size (quantity). The variation in order size of the delivery can be correlated with the delays. Question 15 is designed for finding out whether there is a need for new equipment for modernising the delivery system. Question 16 is designed for enquiring whether the delivery system requires new software. Question 17 is designed for finding out whether there is a need for additional workforce for the delivery system.

The relationship between the customer and the supplier plays an important role in the success of the outsourcing. Question 18 is designed in order to enquire about the nature of the relationship between the company and the supplier. Question 19 is related to the supplier, but it was asked from the company. Question 19 was designed in order to enquire whether the supplier understood the business requirements of the company. The

communication system is another important element of the outsourcing system. Question 20 is designed for enquiring about the inter-communication situation between the customer and the supplier. Question 21 is designed in order to find out whether the company or the supplier has introduced, or is planning, any training programmes for improving the communication system.

Questions 22 to 24 are designed, in order to enquire about the percentage of defective components delivered. Question 22 is designed to find out whether the quality of the supplied components conforms to ISO 9000. Question 23 is designed for finding out the frequency of defective components supplied to the customer. Question 24 is structured in order to find out the number of defective components supplied.

Questions 25 and 26 are designed to enquire about the participation of the supplier in the quality-control programme, and the reasons for despatching of the defective components. Question 27 is designed in order to enquire about the penalty system in case defective components are delivered.

Question 28 is controversial. It is related to the supplier, but is asked of the company. If the answer to question 28 is 'No', it means that the supplier is trying its best to supply the best components, or does not have the capability for improving the components. On the contrary, if the answer is 'Yes', it means that the supplier does not care about the company, or the supplier is unable to offer the best technology at the agreed price.

Question 29 is also asked from the company, in order to find out whether the supplier is considering, or intending to implement, an improvement programme.

Questions 30 to 32 are designed, in order to enquire about information security and the ownership of the equipment and technology. Question 30 is designed in order to enquire whether there is any confidentiality agreement between the company and the supplier. Question 31 is designed in order to enquire whether the design of the equipment is new and cannot be exposed to general knowledge. Question 32 is designed in order to find out the ownership of the technology used for manufacturing the components. It enquires whether the technology used is patented and who owns it, or has bought its patent rights.

Questions 34 to 37 are designed in order to identify the root causes of information leakage. Question 34 is designed for finding out whether the information leakage is because the supplier is collaborating with a number of other companies, and information leakage is accidental or systematic. Question 35 is controversial and very personal. It is designed for investigating whether there is any chance that the information could be sold by the employees to the competitors. Question 36 is designed, for finding out whether leakage of information is due to a lack of security in the communication system. Question 37 is structured for investigating whether the supplier has, or is organising any training programmes for minimising information leakage.

Part2. Quality and Performance: This part lists 16 important manufacturing, quality and management tools. The capability maturity level of the organisation can be evaluated by finding out the implementation level of the tools. The respondents are asked to mark appropriately, if their organisations are employing the listed manufacturing / management tool. (1= fully implemented 2= partially implemented 3= beginning to implement 4= does not have). The respondents were advised to mark '?' if they were not sure about the manufacturing/ management tool.

***Part3. Technologies and Techniques*:** This part lists 13 machine tools and techniques used for advanced manufacturing. The manufacturing capability for providing an acceptable quality is a function of fully-automated computer control machine tools, ranging from raw material handling to intricate operations. The manufacturing capability of a company can be determined by the availability of the modern machine tools. The respondents are asked to mark a particular tool, if they are using the listed manufacturing techniques. The respondents are advised to mark '?' if they are not sure about the manufacturing techniques.

Part4. Education and Training: Education and training signifies the continuous improvement trend. Regular educational and training programmes keep employees updated about new developments in technologies and management techniques. This section is designed to enquire respondents about their education and taining programme.

Part5. Supplier Selection Criteria: In this part 56 criteria are listed. The respondents are requested to tick as appropriate, or suggest their own.

3.10 STRUCTURE OF THE SECOND QUESTIONNAIRE

The second questionnaire consists of nine parts. Part one is structured from eight main supplier selection criteria. Twenty-eight comparisons amongst criteria are structured. The process is started by listing all the criteria in the left-hand column, except the first criterion. The middle column is left blank for the respondent. In the right-hand column, the first criterion is repeated against all the seven listed left-hand column criteria. Then again, in the left-hand column, all the criteria are listed starting from the third criterion. The second criterion is listed in the right-hand column against third to eighth criteria listed in the left-hand column. This process is repeated until all the possible comparisons are achieved.

Similarly, Part two of the questionnaire is structured from two sub-criteria of organisational and environmental law. Part three of the questionnaire is structured from three sub-criteria of technology and manufacturing ability. Part four of the questionnaire is structured from two sub-criteria of financial operation ability. Part five of the questionnaire is structured from eight sub-criteria of reputation. Part six of the questionnaire is structured from two sub-criteria of management and business professionalism. Part seven of the questionnaire is structured from three sub-criteria of effective cost. Part eight of the questionnaire is structured from three sub-criteria of on-time delivery. Part nine of the questionnaire is structured from three sub-criteria of quality.

3.11 PRETESTING AND IMPROVEMENT OF THE QUESTIONNAIRE

Both questionnaires are pretested before mailing to the respondents. In the case of the first questionnaire, the content is analysed in the context of outsourcing of manufacturing operations. The questionnaire sequence and layout is checked by comparison with the flow chart used for generating it. An iterative process is used for pretesting and refining the questionnaire. Once all the possible corrections were made, two fellow researchers were requested to provide feedback. One fellow researcher belonged to the engineering discipline, and the other one to information technology (IT). The aim of the pretesting is to find out how

easily an outside respondent understands the questions. The engineering fellow understood the questionnaire after reading it through few times. There was a request to rearrange some of the questions to create a flow of thoughts. Only part of that feedback was implemented and the questionnaire was modified. The IT researcher spent some time reading the questionnaire and could not understand some of its parts. After explaining the context of the questions, there was a request to elaborate on the questions, so that the respondent could understand the questions clearly. The feedback was implemented.

During pretesting, the questionnaires are restructured. The errors are subsequently corrected. Pretesting of the questionnaire costs time and effort, but is essential for corrections, and extremely useful for improvement.

3.12 QUESTIONNAIRE APPROVAL PROCEDURE BY ETHICS COMMITTEE

All experimental work, which involves the use of human participants, has to be approved by the ethics committee of the University. Both questionnaires are designed following the guidelines of the ethics committee and proper ethical standards are maintained in carrying out the research work. The first questionnaire was submitted to the ethics committee for its approval. It was approved after 3-4 weeks. The ethics committee was to be instructed of any significant changes in the research questionnaire, after approval. The respondents were clearly advised whether their contributions to the research would have any direct or indirect benefit to them. Ethical standards ensure that the data collected remains confidential, and the sensitivity of data must be considered. Any kind of personal information should not be permitted in the public domain.

3.13 QUESTIONNAIRE VALIDATION

After obtaining approval from the ethics committee, the first questionnaire was presented to Newton Equipment for validation. The purpose of the validation was to obtain feedback from experts. The feedback included the total time a respondent takes to answer the questionnaire, and understanding of the wording of the questionnaire.

An appointment was made to see the managing director of Newton Equipment. Newton Equipment was founded in 1978 as a producer of specialist auto-parts. The company sets the standard for quality of design. The managing director of Newton Equipment is a self-made entrepreneur, who also owns Colourite Metal Treatments Limited and various other businesses. He has been involved in the auto business for over fifty years, ranging from manufacturing of precision parts to outsourcing of manufacturing operations. The questions were discussed in detail, one by one. The managing director enquired about the motive of the questionnaire and how its results would be used. The managing director was told that the questionnaire was designed in order to find out the requirements of the manufacturing company already outsourcing, or planning to outsource. For outsourcing, the first step was to find out the requirements of the company for a supplier selection. The outcome of the questionnaire will be used in identifying the requirements of the company. In addition, the questionnaire will also be used for identifying weaknesses in the outsourcing activities. The feedback provided by the managing director of Newton Equipment is as follows:

The structure and language of question 1 is OK. It may be possible that some respondents may be interested in enquiring about the final assembly, even though some companies were outsourcing manufacturing of their components, and were assembling the final product in-house. The question could have been asked as a single phrase, 'Does the company outsource part/all of its manufacturing activities?' Question 2 could have been asked directly, assigning importance weights to cost, delivery and quality. It is a common practice that every company desires a supplier that manufactures on time, best-quality components with the least expense. In this questionnaire, the respondents were asked to assign a degree of importance compared with their competitors. There would be a lengthy calculation involved in calculating the priority weights of cost, quality and on-time delivery. The question could only be tested once the results were validated. Question 3 attempts to find out the perspective of the company regarding order production delay. It may be difficult for the company to answer, unless the company is involved with the supplier; otherwise it will be speculation. Once the company starts outsourcing to the supplier, terminating of the contract is difficult and expensive. One has to be careful when analysing the results of the survey. The answer to question 4 could be any one of the four given choices. It is advisable to consider the location when comparing two suppliers in

terms of time delay. In most cases, the delivery system is an external factor, or a combination of both internal and external influencing factors. Question 5 enquires about delay in delivery due to error in the delivery system. Question 6 enquires about delay in supply orders. It could be due to a number of reasons; the respondents may be using their own initiative. Questions 7 to 12 are sub-parts of question 6. It is suggested to connect questions 6 to 12. Questions 14 to 17 are asked for finding out the need for modernising the delivery system. By analysing the results of questions 6 to 17, the weaknesses in the delivery system could be identified. The weaknesses identified may serve as guidelines for trouble-shooting. Questions 18 and 19 are also applicable to those companies that are already practising outsourcing.

Similarly, questions 20 and 21 are applicable to companies which are already practising outsourcing. Both questions are enquiring about the inter-communication situation between the customer and the supplier. Question 22 is a deciding factor. If the answer is 'NO', there is no need to ask any other questions. The supplier who does not conform to ISO 9000, should not be shortlisted for selection. Questions 23 and 24 can assess a supplier's capability in supplying defect-free lots. There is no harm in asking question 27, but Newton Equipment does not like introducing a penalty system. The meaning of outsourcing is bringing two organisations closer together. If penalties are charged to your supplier, at the end of day the cost has to be recovered from the end-user. Question 28 is controversial; some organisations may not like to answer. The policy of Newton Equipment does not allow selecting the most economical supplier. In response to question 29, if a supplier does not have any improvement plans, then what should be the course of action be born in mind. Newton Equipment prefers a supplier with an improvement plan, but it does not mean that a supplier who does not have an improvement plan in place will not be considered for selection. Newton Equipment selects a supplier if the supplier can integrate with the company. Questions 30 to 37 are applicable to those companies which are already practising outsourcing. Questions 30 to 32 are focused on information security, and questions 34 to 37 are focused on identifying the root causes of information leakage.

The quality and performance part listed important manufacturing, quality and management tools. The answer to the question depends on the level of understanding of the respondents. The supplier is not supposed to apply all the management tools. The implementation of

only a few tools will be sufficient. The technologies and techniques part listed the most common and modern machine tools and techniques used for advanced manufacturing. The suppliers are not expected to have all the machine tools and be practising all the listed techniques.

The managing director of Newton Equipment also added that it is difficult to allocate funds for education and training, without justifying a return in profit. Staff development programmes are beneficial for the companies if organisations can afford the cost.

3.14 CONCLUSIONS

Two questionnaires have been developed successfully by following the guidelines provided in the chapter. The questions were successfully arranged in sequence, in order to create a flow in information acquisition. Finally, the questionnaires were pretested and validated following a systematic procedure.

Chapter 4

OUTSOURCEE (SUPPLIER) SELECTION CRITERIA

4.1 INTRODUCTION

This chapter provides detailed analysis about supplier (outsourcee) selection criteria for small and medium sized manufacturing companies. The criteria selection for choosing a supplier for small and medium sized manufacturing companies consists of a number of stages. It began with a review of criteria used in previously published supplier selection models in the sectors of IT, Services, BPO, Product Design, Engineering and Manufacturing. The number of criteria/sub-criteria used in each of these models varied between 3 and 30. There were over two hundred criteria and sub-criteria identified, which were used by researchers and practitioners for supplier selection. These criteria were then sorted or grouped in such a way that each group represented a similar/same category. These criteria groups were analysed for choosing supplier selection criteria for small and medium sized manufacturing companies. In order to make sure that the most suitable criteria were selected, it was considered essential to prepare a questionnaire for collecting information from small and medium sized manufacturing companies.

Questionnaires were sent to the managers of a number of small and medium sized manufacturing companies. The information collected through the questionnaires was compared with the information obtained from the literature survey. However, the outcome of the comparison was not deemed suitably sufficient for deciding supplier selection criteria.

To enable a more precise selection of criteria it was then decided to set up a number of interviews with the managers of some small and medium sized companies. Eventually, with the help of these managers, a set of eight outsourcee selection criteria with twenty-six sub-criteria was finalised for a satisfactory supplier selection model for small and medium sized companies. This identified specific set of criteria and sub-criteria is relevant for small and medium sized manufacturing companies. In literature similar criteria were generally

treated and used in general context. The identification of the criteria and sub-criteria is carried out based on information acquired from real companies.

4.2 LIST OF CRITERIA

Table 4.1 lists over two hundred supplier selection criteria. These were identified during the literature survey. These criteria were used for supplier evaluation/selection in the areas of IT, services sector, purchasing, design and development and manufacturing sector. The identified supplier selection criteria and sub-criteria were sorted into groups according to their similarities. The number of models/frameworks that have used a particular criterion is presented within the parenthesis of that criterion.

Cost [Canez et al. (2000), Min (1994), Kirytopoulos et al. (2008), Sevkli et al. (2008), Motwani et al. (1999), Yang and Chen (2006)]
Acquisition Cost [Canez et al. (2000)]
Cost – Design & Development [Akomode et al. (1998)]
Design cost [Bhutta & Huq (2002)]
Cost Freight/Transportation [Ting & Cho (2008), Akomode et al. (1998), Kirytopoulos et al. (2008)]
Cost Inventory [Akomode et al. (1998)]
Cost of inspection [Bhutta & Huq (2002)]
Cost Level [de Boer et al. (1998)]
Raw material cost [Bhutta & Huq (2002)]
Labour cost [Bhutta & Huq (2002)]
Machine depreciation cost [Bhutta & Huq (2002)]
Cost of Ordering [Ting & Cho (2008)]
Cost of Production [Canez et al. (2000)]
Cost of Product [Kirytopoulos et al. (2008)]
Quality cost [Bhutta & Huq (2002)]
Purchasing Cost [Ting & Cho (2008)]
Cost Reduction Activities [Canez et al. (2000)]
Re-work cost [Bhutta & Huq (2002)]
Cost due to delay [Bhutta & Huq (2002)]
Cost Relationship Management [Akomode et al. (1998)]
Cost Savings [Canez et al. (2000)]
Price [Xia & Wu (2005), Bayazit (2006), Sevkli et al. (2008)]
Total cost [Akomode et al. (1998), Lasch and Janker (2005)]
Price Control [Bayazit (2006)]
Product Price [Ting & Cho (2008), Choy & Lee (2002)]
Tariffs Cost/Customs Duties [Akomode et al. (1998), Kirytopoulos et al. (2008), Min (1994)]
Turnover [Yang and Chen (2006), de Boer et al. (1998)]
Engineering cost [Bhutta & Huq (2002)]
Compliance with due Date [Choy & Lee (2002)]
Delivery [Canez et al. (2000), Choy & Lee (2002), Sevkli et al. (2008),Yang and Chen (2006), Motwani et al. (1999)]
Delivery Condition [Cebi & Bayraktar (2003)]
Delivery lead Time [Bayazit (2006)]
Delivery on Time [Min (1994)]
Delivery Time [Kirytopoulos et al. (2008)]
Quantity [Lasch and Janker (2005)]
Delivery Quantity Shortage [Ting & Cho (2008)]
Delivery Reliability [Ting & Cho (2008)]
Delivery Time Delay [Ting & Cho (2008)]
Time to market [Canez et al. (2000)]

Lead Time [Choy & Lee (2002), Cebi & Bayraktar (2003), Sevkli et al. (2008)]
Lead Time to Order [Ting & Cho (2008)]
Manufacturing Up-to-date [Sevkli et al. (2008)]
On-Time Delivery [Xia & Wu (2005)]
Orders [Akomode et al. (1998)]
Quality [Akomode et al. (1998), Bhutta & Huq (2002), Bayazit (2006), Motwani et al. (1999), Yang and Chen (2006)]
ISO9000 certification [Kakouris (2006)]
ISO 9000 Quality 5750 [Akomode et al. (1998)]
Quality [Xia & Wu (2005), Canez et al. (2000), Lasch and Janker (2005)]
Quality Image [de Boer et al. (1998)]
Quality Assurance [Min (1994), Sevkli et al. (2008)]
Quality Assurance Production [Choy & Lee (2002)]
Quality Assurance Supply [Choy & Lee (2002)]
Quality Audit [Akomode et al. (1998)]
Quality Control [Min (1994)]
Quality Defects [Xia & Wu (2005)]
Quality Measure [Canez et al. (2000)]
Product Quality [Ting & Cho (2008)]
Quality Planning [Choy & Lee (2002), Sevkli et al. (2008)]
Quality Reliability [Xia & Wu (2005)]
Quality Staff [Choy & Lee (2002)]
Quality System [Canez et al. (2000), Ting & Cho (2008)]
Quality System Assessment / Measurement / Supply [Choy & Lee (2002), Sevkli et al. (2008)]
Quality team Visits [Min (1994)]
Quality Technical Level [Xia & Wu (2005)]
Rejection in Incoming Quality Control [Choy & Lee (2002)]
Total quality management [Kakouris (2006)]
Quality of Personnel in R&D [Chen et al. (2008)]
Communication [Cebi & Bayraktar (2003)]
Ease of Communication [Kirytopoulos et al. (2008)]
Information Systems [Canez et al. (2000)]
Information Technology [Sevkli et al. (2008)]
IT Systems [Yang and Chen (2006)]
Internet [Sevkli et al. (2008)]
Freight Terms[Min (1994)]
Shipment [Sevkli et al. (2008)]
Shipment Quality [Choy & Lee (2002)]
Shipment Tracing [Kakouris (2006)]
Storage [Sevkli et al. (2008)]
Transportation, Storage and Packaging [Choy & Lee (2002)]
Logistics [Cebi & Bayraktar (2003), Lasch and Janker (2005)]
Compliance with Packaging Standards [Choy & Lee (2002)]
Assets & debts [Ting & Cho (2008)]
Cash Flow [Ting & Cho (2008)]
Foreign Exchange Rate [Min (1994)]
Finance [Yang and Chen (2006)]
Financial Operation ability/capability [Mei-yuan et al. (2006), Bayazit (2006)]
Financial Strength/stability/status [Kirytopoulos et al. (2008), Cebi & Bayraktar (2003),Ting & Cho (2008), Min (1994) , Kakouris (2006)]
Financial Conditions [Chen et al. (2008)]
Income & Earnings [Ting & Cho (2008)]
Financial terms [Bayazit (2006)]
Payment terms [Min (1994)]
Return on Investment [Chen et al. (2008)]
Debt Ratio and Refund ability [Chen et al. (2008)]
Investment in R&D [Chen et al. (2008)]
Profitability in the Future [Chen et al. (2008)]
Commitment Project Management [Akomode et al. (1998)]
Management [Cebi & Bayraktar (2003)]
Mutual trust and Commitment [Chen et al. (2008)]
Commitment [Akomode et al. (1998)]

Documentation Processes [Kakouris (2006)]
Management Commitment [Bayazit (2006), Choy & Lee (2002), Sevkli et al. (2008)]
Business [Cebi & Bayraktar (2003), Sevkli et al. (2008)]
Management and Business Professionalism [Mei-yuan et al. (2006)]
Management Capability [Choy & Lee (2002)]
Management Capability Quality [Akomode et al. (1998)]
Management Corporate Culture [Kakouris (2006), Chen et al. (2008)]
Organisation Management [Kakouris (2006)]
Corporation Compatibility [Chen et al. (2008)]
Compatibility of Corporation Strategy [Chen et al. (2008)]
Symmetry of Scale and Scope [Chen et al. (2008)]
Past Cooperation Experience [Chen et al. (2008)]
Continuous Improvement Programme [Canez et al. (2000)]
Engineering Changes Systems [Canez et al. (2000)]
Continuous Improvement Commitment [Kakouris (2006)]
Improvement Effort [Cebi & Bayraktar (2003)]
Process Improvement [Choy & Lee (2002)]
Product Development & Improvement [Chen et al. (2008)]
Product Specification [Kirytopoulos et al. (2008)]
Development [Sevkli et al. (2008)]
Product Development [Choy & Lee (2002)]
Resources for R&D [Chen et al. (2008)]
Inspection and Control/ Experimentation [Choy & Lee (2002), Sevkli et al. (2008)]
Measurements available [Kakouris (2006)]
Performance Image [Akomode et al. (1998)]
Performance Measurement [Kakouris (2006),Sevkli et al. (2008)]
Relationship [Kirytopoulos et al. (2008), Cebi & Bayraktar (2003)]
Service Performance [Min (1994)]
Performance Reliability [Akomode et al. (1998)]
Potential for growth [Chen et al. (2008)]
Enterprise Environment [Mei-yuan et al. (2006)]
Organisational Culture [Choy & Lee (2002)]
Organisational Structure [Sevkli et al. (2008)]
Organisational Profile [Choy & Lee (2002)]
Claims Handling [Kakouris (2006)]
Labour Disputes [Min (1994)]
Legal Claims [Min (1994)
Problem Solving [Kakouris (2006), Cebi & Bayraktar (2003)]
Service [Lasch and Janker (2005)]
Customer Service(s) [Kirytopoulos et al. (2008), Bhutta & Huq (2002), Ting & Cho (2008), Choy & Lee (2002), Yang and Chen (2006)]
Capacity [Akomode et al. (1998), Cebi & Bayraktar (2003), Yang and Chen (2006)]
Capacity Supply [Xia & Wu (2005)]
Capacity Utilisation [Canez et al. (2000)]
Production Capacity [Sevkli et al. (2008), Yang and Chen (2006)]
Production Facilities and Capacity [Kirytopoulos et al. (2008)]
Reputation [Mei-yuan et al. (2006), Cebi & Bayraktar (2003)]
Business Reputation [Kakouris (2006), Sevkli et al. (2008)]
Reputation with Customers [Kakouris (2006)]
Supplier Reputation [Kirytopoulos et al. (2008)]
Supply Contracts [Ting & Cho (2008)]
Present customer contract [Kakouris (2006)]
Regulatory Knowledge [Kakouris (2006)]
Understanding of Pertinent Law [Mei-yuan et al. (2006)]
Patent [Sevkli et al. (2008)]
Process Ownership [Canez et al. (2000)]
Willingness as Partner [Kakouris (2006)]
Willingness to Invest [Kakouris (2006)]
Location/Proximity [Akomode et al. (1998), Sevkli et al. (2008)]

Distance [Yang and Chen (2006), de Boer et al. (1998)]
Equipment/Experience for R&D [Chen et al. (2008)]
Skills to perform the process [Canez et al. (2000)]
Skilled staff [Akomode et al. (1998)]
Personnel Capability [Bayazit (2006)]
Sales Staff Competence [Cebi & Bayraktar (2003)]
Design & Technical capability [Yang and Chen (2006)]
Technical Capability [Sevkli et al. (2008), Choy & Lee (2002), Motwani et al. (1999)]
Technical Skills [Canez et al. (2000)]
EDI Capability [Min (1994), Kakouris (2006)]
EDI [Sevkli et al. (2008)]
RFID [Sevkli et al. (2008)]
Past Experience [Cebi & Bayraktar (2003)]
Training [Sevkli et al. (2008)]
Training Schemes [Canez et al. (2000)]
Buyer –Supplier Partnership [Min (1994)]
Co-design Production [Ting & Cho (2008)]
Cooperation & Partnership [Ting & Cho (2008)]
Dependability [Kakouris (2006)]
Involvement [Cebi & Bayraktar (2003)]
Supplier's Profile [Kirytopoulos et al. (2008)]
Supplier's Certification [Kirytopoulos et al. (2008)]
Collaboration with Supplier [Canez et al. (2000)]
Maintenance [Sevkli et al. (2008)]
Maintenance Activities [Choy & Lee (2002)]
Maintenance Tools [Akomode et al. (1998)]
Inventory Control [Canez et al. (2000)]
Plant Layout and Material Handling [Choy & Lee (2002)]
Contingency Planning Consideration [Kakouris (2006)]
Production Planning System [Choy & Lee (2002)]
Technologic [Cebi & Bayraktar (2003)]
Technical Assistance [Min (1994)]
Technical Expertise [Akomode et al. (1998)]
Technical Innovation [Akomode et al. (1998)]
Capability of Innovation and Invention [Chen et al. (2008)]
Technical Tools [Akomode et al. (1998)]
Technology & Equipment [Canez et al. (2000)]
Technical Support [Canez et al. (2000)]
Manufacturing [Bhutta & Huq (2002), Sevkli et al. (2008)]
Technology Capability [Chen et al. (2008)]
Capability of Manufacturing Technology [Chen et al. (2008)]
Technology & Manufacturing Processes [Canez et al. (2000)]
Technology [Bhutta & Huq (2002)]
Technology and Production Ability [Mei-yuan et al. (2006)]
Security [Kakouris (2006)]
Perceived Risks [Min (1994)]
Risk [Kirytopoulos et al. (2008)]
Speed [Kakouris (2006)]
Supply Lots [Cebi & Bayraktar (2003)]
Counter-trade [Min (1994)]
Warranty Period [Xia & Wu (2005)]
Attitude [Kakouris (2006)]
Cycle Time [Akomode et al. (1998)]
Negotiability [Min (1994)]
Trade Restrictions [Min (1994)]
Vision [Kakouris (2006)]
Performance Market Share [Akomode et al. (1998)]
Market Share [Kirytopoulos et al. (2008), Bayazit (2006)]
Response to Change [Ting & Cho (2008)]

Response to Inquiry [Ting & Cho (2008)]
Responsiveness [Kakouris (2006)]
Cultural Similarity [Min (1994)]
Cultural and Communication Barrier [Min (1994)]
Ethical Standards [Min (1994)]
Political Stability [Akomode et al. (1998), Min (1994)]
Environmental Concern [Kakouris (2006)]
Defect and Scrap Ratio [Ting & Cho (2008)]
Product Rejection Ratio [Ting & Cho (2008)]
Rejection from Customer [Choy & Lee (2002)]
Rejection in Production Line [Choy & Lee (2002)]
Repair turn-round time [Xia & Wu (2005)]
Flexibility [Canez et al. (2000), Cebi & Bayraktar (2003), Bayazit (2006)]
Ability to cope with volume changes [Canez et al. (2000)]
Human Resources [Sevkli et al. (2008)]
No of Employees [Sevkli et al. (2008)]
No of Technical Staff [Sevkli et al. (2008)]
No of Personnel in R&D [Chen et al. (2008)]

Table 4.1: Groups of Supplier Selection Criteria and Sub-criteria

4.3 QUESTIONNAIRE SURVEY FOR CRITERIA SELECTION

Most of the supplier selection models and frameworks identified from the literature review were related to outsourcing of IT, services sector and Business Process Outsourcing. There is a significant operational difference amongst manufacturing organisations, information technology companies, service industries and any other outsourcing sectors. There is a lack of research on supplier selection in small and medium sized manufacturing companies. It was necessary to acquire information about supplier selection criteria for small and medium sized manufacturing companies from the decision-makers of manufacturing companies. A questionnaire was prepared for collecting data related to the outsourcing operations and supplier selection criteria from manufacturing companies.

For ease of understanding, the questionnaire was divided into five parts. Part 1 of the questionnaire comprises thirty-six questions. The questions are designed for acquiring information such as: defects (weaknesses) in outsourcing of manufacturing activities, causes of defects, and occurrence frequency of defects.

Part 2 of the questionnaire consists of sixteen questions, which are related to quality and performance. This part is designed for finding out the extent to which the outsourcing

participants are using manufacturing and management tools. The capability/maturity level of the organisation is evaluated by establishing the implementation level of the tools.

Part 3 of the questionnaire comprises questions which are relevant to modern technologies and techniques. This section is designed for finding out the technological capability and techniques available to the supplier company. The manufacturing capability of a company can be determined by the availability of modern machine tools, such as fully-automated computer controlled and precision machine tools.

Part 4 of the questionnaire consists of five questions, which are designed for assessing the educational and training activities of an organisation, and to find out whether the participants are involved in personnel development.

Part 5 of the questionnaire is an open-ended question that requests respondents to select outsourcee selection criteria from a given list, or suggest their own. The questionnaires and their detailed preparation procedure are attached in the appendices A, B, C and D.

All experimental works, which involved the use of human participants, had to be approved by the ethics committee of the University. After approval from the ethics committee, the first questionnaire was presented to Newton Equipment for feedback. The feedback included the total time a respondent would take in answering the questionnaire and understanding the wording of the questionnaire. The feedback received from the managing director was incorporated.

The respondents were appropriately advised about the research. Ethical standards were followed in keeping the data confidential, and the sensitivity of the data was considered.

For data collection, manufacturing companies practising outsourcing were selected using search engines such as 'Kampass' and 'Fame'. The questionnaire was electronically mailed to over six hundred addresses and more than ten personal contacts were used. From the electronic mail, however, the response was not encouraging. Most of the useful responses were acquired through direct and indirect personal contacts.

Most of the respondents did not select the supplier selection criteria from the provided list. Only a few of them selected the criteria from the list and suggested their own.

4.4 FINAL SELECTION OF CRITERIA THROUGH INTERVIEWS

The literature review and questionnaire survey produced a significant amount of information. But based on that information it was not possible to select the most suitable outsourcer's selection criteria. Thus further information was needed in order to choose the criteria for the outsourcee selection model for small and medium sized manufacturing companies. Therefore, a number of semi-structured interviews were conducted with the managers of a number of manufacturing companies. The managers were not comfortable with the supplier selection criteria list that was prepared by carrying out a literature review and questionnaire survey. The managers proposed that the selected criteria must take into account the aspects of cost, delivery, quality, reputation, finance, technology, management and environmental.

Excerpts of interviews are given as follows:

The managing director of one of the companies advised of the need to find out about the quality control programme, indirectly, from the candidate supplier organisations. This could be done by checking the products already manufactured by the supplier for other companies, and its case history.

He showed a component supplied by his outsourcee that had become discoloured over time, and now his company was having to replace the component, in order to restore the colour. That was an additional cost to his company. This outsourcee company specialised in material processing. The component was perfect in its dimensions, weight and appearance when supplied.

However, the component was designed for the luxury market and appearance is important, but over a period of time the component became discoloured. There was an urgent need to find a solution; otherwise the company would end up losing its reputation. The problem can be resolved in the short-term by replacing the defective component with a new

component; however, the new, replaced part will again discolour with time. Hence, it is necessary to find out the real cause for discolouration of the component. Further investigation established that the material processing company had produced the aluminium alloy, using reprocessed material, which is responsible for undesired properties. During interviews it was made apparent that quality should be considered in terms of material used to manufacture the product, design of the product and standard of the product itself. Thus, 'Material Standard, 'Design Standard' and 'Product Standard' are chosen as the sub-criteria of 'Quality'.

The managing director related another outsourcing experience in order to justify the selection of suitable supplier based on delivery. A supplier was selected to outsource manufacturing a specific component in China. Considering the specific components, the supplier presumed quantity in multiples of 100,000 and quoted the price. The supplier was then informed that the company could consume only 20% of the presumed quantity. The Chinese supplier refused to go ahead with the agreement. Upon further inquiry, the supplier indicated that it was not profitable. The supplier was offered an even higher price but still refused to sign the contract to manufacture for the company.

The managing director suggested that a suitably selected supplier should be able to supply at a cost that is competitive, consistent and sustainable. Based on the information collected from the literature review, questionnaire survey and interviews, it was decided to select 'Effective Cost' as the main criterion and 'Competitive Cost', 'Consistent Cost' and 'Sustainable Cost' as its sub-criteria.

Finally, eight criteria with twenty-six sub-criteria are defined mainly through the interview process and are presented below. Support in literature of similar criteria used in other areas of outsourcing, is also considered. The detailed interviews are attached in appendix E-interviews.

4.4.1 ORGANISATIONAL AND ENVIRONMENTAL LAWS

The criterion 'Organisational and Environmental Laws' is used to find out how well a manufacturing supplier is familiar with intellectual property laws and business rules.It

comprises intellectual property protection laws and business rules. The intellectual property protection laws deal with intangible assets, such as copyright, trademarks, patents, industrial design rights and trade secrets. With the rise in outsourcing, intellectual property protection laws have become increasingly important. In the outsourcing of manufacturing, it may be possible that any one of the following is patented: the product design, the manufacturing process, the material of the product, and technology used for manufacturing the product. The ownership of the patent may belong to the company, or the supplier or third party. Therefore, it is important that once the outsourcing contract terminates, the company and the supplier are clear about their right to manufacture the product. The patent regulations include intellectual property protection and ownership of the patent. Sevkli *et al.* (2008) used 'Patent' as a sub-criterion in the supplier selection model for supply-chain management. Mei-yuan *et al.* (2006) used 'Understanding of pertinent law' as part of the main criterion. Regulations include regulatory knowledge and procedures for legal claims handling, and understanding of pertinent law. Patent regulations include intellectual property protection and ownership of the patent. In order to avoid any later problems, it is necessary that the supplier companies understand pertinent laws and intellectual property protection laws; otherwise, it becomes difficult to incorporate cost of patent (cost of patent or process ownership).

The business rules describe the operations and constraints applied to a company. The business relationship amongst companies matures well if they have compatible organisational structures and Environments. During interviews, it was found that the organisational culture also plays an important role in developing good relationships between a company and its suppliers. It is also recommended taking into account organisational structure and its culture, prior to supplier selection. Choy and Lee (2002) have used 'Organisational Profile' as the main criterion and 'Organisational Culture' as a sub-criterion for supplier evaluation. Mei-yuan *et al.* (2006) used 'Enterprise Environment' as a criterion and Sevkli *et al.* (2008) used 'Organisational Structure' as a sub-criterion.

The questionnaire survey was carried out because there was a need for a supplier selection criterion that reflects the understandings of its supplier about intellectual property protection laws and business rules. While filling out the questionnaires, the respondents showed an interest in organisation, Environmental and organisational structure; despite the

fact that the structure, the Environmental and the culture of an organisation depend on its laws. The respondents did not choose them as a criterion from the questionnaire list.

The information about Organisational and Environmental Laws was collected through the literature review and further clarified by interviews with the managers of the company. The managers explained that the company rules and its Environmental laws should be selected as one of the criteria. The criterion must reflect the understanding of the supplier regarding business rules and knowledge about intellectual property. During interviews it was found that a suitable supplier must understand the environmental and the market requirements of the company. The limitations of the company are defined by the market requirements. After analysing the information collected through the literature review and field survey, 'Organisational and Environmental Laws' was selected as the main criterion for the supplier selection model. 'Intellectual Property Protection Law' and 'Outsourcee Understands Business Rule' were selected as the sub-criteria.

4.4.2 TECHNOLOGY AND MANUFACTURING ABILITY

The criterion 'Technology and Manufacturing Ability' is used for evaluating the technological and manufacturing ability of a supplier. The technical capability of an organisation is determined by technical expertise, technical assistance/support and technical innovation. The manufacturing ability of an organisation is determined by the technology, tools and equipment, and production ability.

Xia and Wu (2005) used 'Technical Level' as the sub-criterion for supplier selection in volume-discount Environmentals. Weber *et al.* (1991) quoted fifteen articles that have used 'Technical Capability' as a supplier selection criterion. Yang and Chen (2006) used 'Design and Technical Capability' as a supplier selection criterion. Chen *et al.* (2008) used 'Technology Capability' as a supplier selection criterion for strategic alliance.

The total number of employees, number of technical staff and their technical capability and technical skills, determines the personnel capability of a company. The personnel and process capability are very much related to the skills, knowledge and technical and technological expertise of the staff, since the personnel and process capability cannot be

acquired without having the right equipment and machine tools (hardware). In the questionnaire survey, the majority of the respondents chose 'Personnel Capability', rather than 'Technical Expertise'.

In the questionnaire survey, three criteria are listed: 'Process Capability', 'Process Ownership' and 'Process Improvement'. The respondents chose 'Process Capability' as a criterion for supplier selection. The third part of the questionnaire covers the technologies and techniques possessed by the respondent company. The whole range of machine tools, such as numeric control machines and industrial robots form part of the hardware. It was not considered necessary to enquire about hardware as a supplier selection criterion.

The personnel capability also explains qualification and experience of the staff. During interviews, the managers explained that for selecting a manufacturing supplier, 'Process Capability' is a suitable criterion. It may be possible that every company may not have the ownership of the process due to intellectual property laws. If the process is patented, in that case 'Process improvement' may not be the appropriate criterion. Thus 'Process Capability' is selected as one of the sub-criteria in order to evaluate the technology and manufacturing ability of a supplier.

The managers also acknowledged that 'Hardware' should be selected as one of the supplier selection sub-criteria. Thus, by taking into account information collected through discussions with the managers, 'Hardware' was selected as one of the sub-criteria in order to evaluate the 'Technology and Manufacturing Ability' of a supplier.

In conclusion 'Hardware', 'Process Capability' and 'Personnel Capability' are selected as the sub-criteria for 'Technology and Manufacturing Ability' in order to select a suitable supplier for outsourcing of manufacturing operations.

4.4.3 FINANCIAL OPERATION ABILITY

The financial soundness of a company is determined by its assets, debts, cash flow and revenue-generation capability. The criterion 'Financial Operation Ability' was chosen for assessing the financial ability of the supplier by investigating how long the supplier has

been in business, without being subjected to bankruptcy or receivership. According to the information acquired through interviews, a suitable supplier should be selected subject to the conditions that the supplier has been in business longer than three years, and is financially in a stable position. The last decision a company should make, is not to start a business with a company that is on the brink of bankruptcy.

Bayazit (2006) used 'Financial Capability' as one of the decision attributes (criteria) in vendor selection decisions. Cebi and Bayraktar (2003) have used financial strength as the sub-criterion for supplier evaluation. Kirytopoulos *et al.* (2008) have used financial status to select a supplier in the pharmaceutical industry. Min (1994) has used 'Financial Stability' as a sub-criterion of the buyer/supplier partnership for an international supplier selection model. Ting and Cho (2008) have used 'Financial Status' as one of the main criteria, in order to select the supplier, by employing an integrated approach. The Financial Status' was divided into three sub-criteria: 'Assets and Debts', 'Income and Earnings' and 'Cash Flow'. Weber *et al.* (1991) quoted seven publications that have listed 'Financial position' as a supplier selection criterion. Chen *et al.* (2008) used 'Financial condition' as a supplier selection criterion and 'Return of investment', 'Debt Ratio and Refund Ability', 'Profitability in the Future' and 'Potential for Growth' as sub-criteria. Ting and Cho (2008) included 'Financial Status' as a supplier selection criterion and 'Assets & debts', 'Income & Earnings' and 'Cash Flow' as its sub-criteria. Cebi and Bayraktar (2003) used 'Financial strength' as a sub-criterion for supplier selection.

In the questionnaire survey, the majority of the respondents selected 'Financial Stability' as one of the supplier selection criteria. During interviews, the managers acknowledged the importance of 'Financial Stability' as a supplier selection criterion, but they were not sure how to easily assess it. The criteria such as 'Assets and debts', 'Cash Flow', 'Income and Earnings' and 'Financial Strength' can be used to describe the financial stability of a company. For selecting an outsourcee, financial soundness is a must.

The managers also suggested finding out whether the company had any record of bad credit or receivership. The financial stability of a company can be related to its bankruptcy or receivership position. Thus 'Not Subjected to Receivership or Bankruptcy' was selected as one of the sub-criteria of 'Financial Operation Ability'.The sub-criterion 'Not Subjected

to Receivership or Bankruptcy' can provide sufficient information about the financial stability of a company. A new, inexperienced company could be selected as a supplier because there would be no record of bankruptcy or receivership.This could create an atmosphere of uncertainty. The managers suggested that it would be safe if another sub-criterion is selected to find out how long the company had been in business. A company should be selected as a supplier if it is not subjected to bankruptcy or receivership and has been in business for over three years. Thus, 'Time (duration) in Business by the Supplier' is selected as a second sub-criterion of 'Financial Operation Ability'.

After analysing the information collected through the literature survey, questionnaire survey and discussions with the managers of the manufacturing companies, it was decided that 'Financial Operation Ability' should be chosen as supplier selection criterion and 'Not Subjected to Receivership/Bankruptcy'and'Time in Business by Outsourcee' as the sub-criteria.

4.4.4 REPUTATION

Reputation determines the ability of a supplier to work with a number of other companies and develop good relationships. The reputation also includes the usage of a secure communication system used by the supplier, responsiveness to change, and participation of the supplier in improvement programmes.

Sevkli *et al.* (2008) used reputation as a sub-criterion in the supplier selection model for supply-chain management. Cebi and Bayraktar (2003) have used reputation as the sub-criterion for supplier evaluation. The managing director of Newton Equipment suggested that it is always preferable to establish business contacts with a company that has a good reputation, rather than the other way around. Now the question arises as to how the assessment of organisations should be carried out in terms of reputation.

The reputation of a company determines its influence in the sector. It also assesses the accessibility of a company to external resources, and how easily external resources are available. During interviews, the managers explained that the reputation of a manufacturing supplier is assessed by how many suppliers are linked with the supplier,

whether linked suppliers comply with ISO 9000 standards and how good the relationship amongst them is. Responsiveness to change, flexibility to adjust to changes, and secure communication, also contribute to reputation.

By carrying out a literature survey, it was found that the responsiveness of an outsourcee plays a crucial role in the success of a business. The responsiveness of a company does not add value directly, but helps in attracting more business. When selecting an outsourcee, it is always advisable to select an organisation which responds efficiently to any inquiry or change. Ting and Cho (2008) have used 'Response to Change' and 'Response to Inquiry' as sub-criteria in order to select the supplier, by employing an integrated approach.

The managers suggested that a suitable supplier must have the characteristic of responding to any changes as quickly as possible. The responsiveness to change characteristics of a company does not increase its monetary value, rather increases its reputation. It was decided that for outsourcing of manufacturing operations, 'Responsiveness to Change' could be selected as a sub-criterion for supplier selection.

The managers suggested taking into account the cultural and ethical aspects because the targeted suppliers are often based abroad, or in a region where the majority of the employees belong to different cultural backgrounds. The supplier should be compatible with respect to its cultural similarity, ethical standards and political stability. The flexibility, negotiability and customisation of a company can enhance its reputation, and provides a competitive advantage over its competitors. Hence, for outsourcing of manufacturing operations, 'Flexibility to Adjust Changes' is also selected as a sub-criterion of 'Reputation'.

The literature survey shows that a suitable supplier should be linked with a number of low-tier suppliers. For instance, due to some or other reason, the company requests a large number of items for manufacturing. If the supplier is connected with a number of low-tier suppliers, the excessive manufacturing load can be transferred easily, without any delay. This enhances its reputation. Thus 'Link with a Number of Suppliers' is selected as another sub-criterion for reputation.

For selecting a supplier, it was important that the chosen supplier had been complying with quality standards. The questionnaire survey analysis shows that the majority of the respondent companies have encountered a 1% - 5% frequency of defective components. In the questionnaire, the option, 'frequency of defective components delivered/supplied >10%' was not included. The manufacturing companies experiencing a frequency of defective components >10%, are not to be considered as supplier (outsourcee). The results of the survey analysis were discussed with the managing director of the company. It was agreed that frequency of defective components less than 5% is acceptable. However, frequency of defective components delivered/supplied less than 1%, is considered to be the most suitable. The percentage number of defective components supplied and percentage frequency of defective components supplied is approximately the same, between 0% - 5%. After discussion with the managing director of Newton Equipment, it was decided that 'Linked Suppliers Comply Quality Standard' should be selected as one of the sub-criteria for 'Reputation'.

The literature survey shows that a secure communication system facilitates in maturing relationships between a company and its suppliers. Having a secure communication system, the participants are not disturbed by external interruptions and breakdowns in information transformation. Kirytopoulos *et al.* (2008) have used 'Ease of Communication' as a sub-criterion to select a supplier in the pharmaceutical industry. Sevkli *et al.* (2008) used 'Information Technology' as one of the main criteria for a supplier selection model for supply-chain management.

The questionnaire survey revealed that in the majority of leakage occurrences, the information leakage was accidental. Only a small fraction could be due to mistakes, because the companies did not have an information secrecy system in operation. During interviews, the managers agreed that a secure communication system was essential for outsourcing and could enhance the reputation of the manufacturing company. Therefore, in outsourcing of manufacturing operations, 'Secure Communication System' is chosen as the sub-criterion for supplier selection.

The performance of an organisation can be assessed by investigating its ability to comply with standards. The performance image of an organisation depends on the reliability of its

suppliers. The managers explained that most of the time, the customers' companies wanted to know about their suppliers, because the product the customer will be receiving may be coming from those suppliers. Thus 'Information Declaration about Linked Suppliers' is selected as the sub-criterion for 'Reputation'.

Cebi and Bayraktar (2003) have used improvement efforts as one of the sub-criteria for technology for supplier evaluation. Participation of a supplier company in improvement programmes does not increase the assets of a company; rather it enhances its reputation. Therefore, 'Linked Suppliers Participate in Improvements' is selected as one of the sub-criteria of 'Reputation'.

It is considered important that the selected outsourcees are flexible and can accommodate changes. The flexibility of a linked supplier does not add value to the assets of a company. It may enhance the reputation of the supplier and of the company. Ting and Cho (2008) have used 'Cooperation and Partnership' as a selection criterion in order to select the supplier, by employing an integrated approach.

The managing director of Newton Equipment emphasised that the manufacturing companies, which are willing to commit as partners, should have a tendency to train their staff in relationship development. Trained staff that are capable of relationship development, also enhance the reputation of the organisation. A company's good relationship with a linked supplier does not add value to its assets, but enhances its reputation. Hence 'Good Relationship with Linked Suppliers' is also selected as one of the sub-criteria for 'Reputation'.

Thus, 'Reputation' is defined in terms of eight sub-criteria: 'Responsiveness to Change', 'Flexibility to Adjust Changes', 'Link with a Number of Low Tier Supplier', 'Linked Suppliers Comply Quality Standards', 'Secure Communication System', 'Information Declaration about Linked Suppliers', 'Secure Communication System', 'Information Declaration about Linked Suppliers', 'Linked Suppliers Participate in Improvements' and 'Good Relationship with Linked Suppliers'.

4.4.5 MANAGEMENT AND BUSINESS PROFESSIONALISM

The criterion 'Management and Business Professionalism' deals with the assessment of the management aspect and business professionalism of the supplier. Sevkli *et al.* (2008) used 'Management Commitment' as a sub-criterion in a supplier selection model for supply-chain management. Choy and Lee (2002) have used 'Management Commitment' as a sub-criterion for supplier evaluation. In the questionnaire survey, some of the respondents have chosen 'Management Capability' as one of the supplier selection criteria.

The managers of Newton Equipment, Totalli SRL and Sonic Enterprise willingly share the information and cooperated with the research. During interviews, the managers of Newton Equipment and Sonic Enterprise suggested that a supplier should have the capability to understand the requirements of the company. The workforce should have the expertise to establish good professional relationships with linked companies in order to work as a team. The understanding of customer's requirements and capability in relationship development can be expressed as business professionalism. The professionalism of an organisation is very much linked with the ability of its staff when dealing with other companies. For outsourcing of manufacturing operations, it is necessary for a company to have trained staff in order to manage its outsourcing activities.

Finally, after analysing the information collected through the literature survey, questionnaire survey and discussions with the managers, 'Management and Business Professionalism' was chosen as the main criterion and 'Understanding of Customer's Requirements' and 'Trained Staff for Relationship Development' as sub-criteria for supplier selection.

4.4.6 EFFECTIVE COST

Effective cost is explained as the ability of the supplier to manufacture products at a sustainable cost that is both competitive and consistent. The total outsourcing cost of manufacturing operations is composed of a number of cost types: fixed cost, operational cost, improvement cost, product acquisition cost, transportation cost, taxation cost, outsourcing management cost and hidden costs. The above-listed criterion and its sub-

criteria address only the static aspects of the cost which means the value of cost at a certain moment in time. There is a need for incorporating dynamic aspects of the cost, in order to keep it stable over a long period of time. In general, the outsourcing cost of manufacturing operations depends upon production (manufacturing) cost, transportation cost and taxation cost. The manufacturing costs consist of cost of materials, direct labour cost, indirect labour cost, machine tool cost (depreciation cost, investment cost), energy consumption cost, process/technology patent (if applicable) cost, manufacturing facility cost, building cost (investment cost) and local taxation and excise duties. In the case of outsourcing, the transportation cost is also added to the acquisition cost (manufacturing cost of the supplier). The transportation cost depends upon the location of the supplier and the mode of transportation (land, sea, air) used. Taxation cost includes the taxes paid overseas and inland (import/export duties). The slightest change in any of the components of cost may influence the outsourcing cost of manufacturing.

Bayazit (2006) used 'Price' as one of the decision attributes (criteria) in vendor selection decisions. Bhutta and Huq (2002) have used total cost of ownership for supplier selection. The total cost of ownership comprises manufacturing costs (raw material costs, labour and machine depreciation), quality costs (costs of inspection, rework costs and costs due to delay), technology costs (design costs and engineering costs) and costs of after-sales service. For supplier selection in the pharmaceutical industry, Kirytopoulos *et al.* (2008) have used 'Cost' as a main criterion, composed of product price, freight cost and duties and taxes. Choy and Lee (2002) have used 'Product Price' as a sub-criterion of 'Technical Capability' for the selection and management of the supplier relationships in an outsourced manufacturing Environmental. Min (1994) has also used 'Cost' as a sub-criterion in his international, supplier selection model. Sevkli *et al.* (2008) have used 'Cost' as a sub-criterion in a supplier selection model for supply-chain management. Ting and Cho (2008) have used 'Purchasing Cost' as one of the main criteria in order to select the supplier, by employing an integrated approach. The 'Purchasing Cost' was divided into three sub-criteria: 'Product Price', 'Transportation Cost' and 'Ordering Cost'. Xia and Wu (2005) have used 'Price' as the main criterion for supplier selection in volume-discount Environmentals.

The questionnaire survey analysis shows that the majority of the respondent companies have marked 'important', in having lower costs than their competitors. The respondents did not select any of the criteria from the provided list. The information acquired through the literature survey and questionnaire was not sufficient for selecting the criteria and sub-criteria relevant to cost. The interviews were conducted for acquiring in-depth information regarding supplier selection criteria. The information extracted from the literature review, questionnaire survey and interviews showed that for selecting the right outsourcee, one should concentrate on effective cost rather than low cost. The effective cost of an outsourcee is determined by its ability to provide a product at a cost that is consistent, competitive and sustainable. Thus, the main criterion, 'Effective Cost' is evaluated in terms of three sub-criteria: 'Consistent Cost', 'Sustainable Cost' and 'Competitive Cost'.

The literature review and questionnaire survey did not provide any information about the importance of 'Competitive Cost' for supplier selection. Only during interviews, the managers suggested that a suitable supplier must be able to manufacture at a competitive cost, rather than the cheapest cost, i.e., the cost must be comparable with other suppliers in the same sector.

Similar to the 'Competitive Cost', the selection of 'Consistent Cost' as the sub-criterion of 'Effective Cost' was recommended by the managing director of Newton Equipment. The consistent cost is the ability of a supplier not to change its cost with a change in order sizes. The managing director of Newton Equipment suggested that the supplier must be able to manufacture at a consistent cost and sustainable cost despite changes in the order size. The sustainable cost is explained as that which is affordable and unchanged over a period of time.

4.4.7 ON-TIME DELIVERY

Acquisition or supply of products timeously is very important in outsourcing. Theoretically, an ideal outsourcee must have the capability of delivering products with consistency and with documentation.

The outcome of the literature search has identified criteria related to delivery which varied from 'Lead Time to Order' to 'Compliance with due Date'. Bayazit (2006) used 'On-Time Delivery' as one of the decision attributes (criteria) in vendor selection decisions. Cebi and Bayraktar (2003) have used 'Delivery Condition' as a sub-criterion for supplier evaluation. Choy and Lee (2002) have used 'Delivery' as a sub-criterion of 'Technical Capability'. Kirytopoulos *et al.* (2008) have used 'Delivery Time' as the sub-criterion for supplier selection in the pharmaceutical industry. Min (1994) has used 'On-Time Delivery' as a sub-criterion in its international supplier selection model. Sevkli et al. (2008) used 'Delivery' as a sub-criterion in a supplier selection model for supply-chain management. 'Delivery' has been used for performance assessment in order to select the supplier. Ting and Cho (2008) have used 'Delivery Reliability' as one of the main criteria in order to select the supplier, by employing an integrated approach. 'Delivery Reliability' was split into two sub-criteria: 'Delivery Time-Delays' and 'Delivery Quantity-Shortage'. Xia and Wu (2005) have used 'On-Time Delivery' as the sub-criterion for supplier selection in volume-discount Environmentals.

The questionnaire survey analysis shows that the majority of the respondent companies have declared 'fast' deliveries (compared with respondents) 'important'. In case the outsourcee is based overseas, it is advisable to receive documentation in advance for customs and excise clearance, to avoid any demurrage. In the case of outsourcing of manufacturing products, external management is involved and may be based abroad. It is always considered wise to have complete delivery documents on time; otherwise the delivery may not be processed. During interviews with the managers, it was found that delivery lead time and delivery consistency were very important in outsourcing. The manufacturing time for the product could be hours or weeks, but the transportation time, for example from China to Europe, is weeks. Therefore in order to assess the on-time delivery, the delivery lead time should take into account the transportation time in weeks. Similarly, consistent delivery was considered important because the manufacturing and transportation responsibilities were outsourced.

The criterion 'Delivery Documentation' covers complete detail of the product (part type, quantity, and certification) in the form of documents and their availability, well before time. The managing director of Newton Equipment explained that delivery documents

should be sent by the supplier earlier than the delivery is expected. It takes some time for customs clearance. If the documents are not complete, the delivery will not be released and the company will be held responsible for paying the demurrage.

Thus 'On-Time Delivery' was selected as the main criterion to assess the supplier in terms of delivery and is divided into three sub-criteria: 'Delivery Lead Time', 'Delivery Consistency' and 'Delivery Documentation'.

4.4.8 QUALITY

As a result of the literature survey, a number of supplier selection criteria, relevant to quality, were identified. The criteria of quality varied from 'Quality' to 'Total Quality Management'. Despite the fact the same name was used for some criteria. The specific meaning was slightly different from one company to another. The researchers and practitioners have used the criterion of quality in a very broad sense in their model formulations. For example, in the case of a process, quality is determined by its waste elimination, in reducing cost. The elimination of waste is the minimisation of the rejection in the production line, and the rejection from the customer. There are a number of criteria which can be used for assessing the quality of manufacturing.

Bayazit (2006) used 'Quality' as one of the decision attributes (criteria) in vendor selection decisions. Choy and Lee (2002) have used 'Quality Assessment' as one of three main criteria for supplier evaluation and 'Quality Planning', with 'Quality Assurance Supply', 'Quality Staff' and 'Quality Assurance Production' as the sub-criteria. Kirytopoulos *et al.* (2008) have used product specifications and supplier's certification for quality cluster in order to select a supplier in the pharmaceutical industry. Min (1994) has used 'Quality Control' and 'Quality Team Visits' as sub-criteria of 'Quality Assurance' for an international supplier selection model. Sevkli *et al.* (2008) used 'Quality Planning' and 'Quality Assurance' as sub-criteria for a 'Quality System Assessment' criterion in a supplier selection model for supply-chain management. Ting and Cho (2008) have used 'Product Quality' as one of the main criteria in order to select the supplier, by employing an integrated approach. The 'Product Quality' was divided into three sub-criteria: 'Defect and Scrap Ratio', 'Product Rejection Ratio' and 'Quality System'. Xia and Wu (2005)

have used 'Quality' as the main criterion and 'Technical Level', 'Defects and Reliability' as the sub-criteria for supplier selection in volume-discount Environmentals.

The analysis of the questionnaire survey shows that the majority of the respondent companies consider superior quality, compared with their competitors, as 'very important'. It might be possible that during model application, the companies which had assigned higher priority to on-time delivery might not expect to receive good quality products and low cost.

After conducting interviews, it was found that for outsourcing of manufacturing operations, the quality of the outsourced product is assessed in terms of its design, its compliance with ISO 9000 and the standard of its material.

The product standard is expressed in terms of its operational capability, safety features, aesthetics, appearance and colour. In the outsourcing of manufacturing, either the company provides the product design to the manufacturing supplier, or instructs the supplier to design the product and manufacture for the company. In both cases the product design should conform to ISO quality standards.

The managing director of Newton Equipment also explained that each material has its own innate properties, such as hardness, melting point, toughness, durability, corrosiveness. When a product is designed, there are other properties (physical appearance, safe for physical contact) which are taken into account. If a product and its design conform to ISO quality standards, then the material used should also be according to ISO standards.

Finally, it was agreed that in outsourcing of manufacturing operations, the quality of a manufactured product should be assessed by product standard, design standard and standard of the material used for its manufacture.

4.5 CONCLUSIONS

The identification of outsourcers' criteria for outsourcee selection was carried out systematically in stages: literature survey, questionnaire survey and discussions /

interviews with managers of Newton Equipments and Sonic Enterprise.With the assistance of managers a set of eight criteria and twenty-six sub-criteria were identified.

All outsourcee selection criteria and sub-criteria are defined to meet the requirements of small and medium size manufacturing outsourcing companies, approved by the managers of manufacturing companies. The identified criteria and sub-criteria address all aspects of cost, delivery, quality, reputation, finance, technology, management and environment. They are different and yet retain the essence of the criteria and sub-criteria used in previously published supplier selection models and frameworks in the IT, Services, Product Design, Engineering and Manufacturing sectors.

Furthermore, the procedure followed in this research for the identification of criteria is systematic and well structured.

Chapter 5

NUMERICAL EVALUATION OF OUTSOURCER'S SELECTION CRITERIA

5.1 INTRODUCTION

This chapter presents the detail and application of the model which converts subjective opinions into objective judgements for numerical evaluation of outsourcer's criteria for outsourcee selection in small and medium sized manufacturing companies. The model employs the analytical hierarchical process (AHP) and cluster analysis (CA) for group decision analysis, in order to evaluate the relative priority weights of outsourcee selection criteria and sub-criteria. The data used and the results are based on real companies. The procedure to calculate priority weight of each of the selection criteria and sub-criteria is incorporated in detail.

The data collected using the second questionnaire from manufacturing and outsourcing managers, showed a range of variation caused by the bias of the replies (according to experience and field of expertise of the respondents). The data in their raw form were not useful for making decisions. Therefore, there was a need for transforming subjective opinions into objective output. This was subsequently achieved by designing a model for this conversion.

In order to find the appropriate method used by other researchers in transforming subjective opinions into objective judgements, a literature search was carried out. According to the literature review, Wray *et al.* (1994) used neural network for analysing the buyer/seller relationship, and Drake (1998) applied the AHP for real engineering selection problems, whereas Bhutta and Huq (2002) applied total cost of ownership and AHP for supplier selection. Additionally, Bayazit (2006) used AHP in evaluating supplier selection problems. Sevkli *et al.* (2008) applied the AHP integrated with fuzzy linear programming to solve the supplier selection problem of a Turkish-based appliance manufacturer.

The analytical hierarchy process was developed by Thomas Saaty in 1971 (Saaty, 1980) ; (Saaty and Alexander, 1981). Chen and Chen (2006) highlighted the importance of clustering. The supplier evaluation, qualitatively and/or quantitatively for selection, has been carried out by applying AHP, rating systems, mixed integer, goal and multi-objective programming (Bhutta and Huq, 2002); (Cebi and Bayraktar, 2003).

The analytical hierarchy process is used to change a subjective criteria score assigned by a decision-maker into relative objective importance (priority) weights. The information was collected from a number of decision-makers (experts). It was important to find a suitable tool for merging the opinions of a number of decision-makers into one standard. Cluster analysis is considered a suitable tool because it groups companies/decision-makers according to their calculated weightings. Mei-yuan *et al.* (2006) applied the principles of AHP and cluster analysis based on group decision analysis in evaluating and selecting software outsourcing. Thus, a Mathematical model is formulated using the analytical hierarchy process and cluster analysis to show how raw data should be transformed into matrices and surveyed eigenvectors. The result is an eigenvector that is representative of the entire range of companies surveyed and in this study is defined as priority wight vector of criteria. The elements of the priority weight vector represent the relative priority weights of criteria.

5.2 EVALUATION OF PRIORITY WEIGHTS OF CRITERIA

The selection criteria and sub-criteria were arranged into a hierarchy structure in accordance with Saaty's (1980) guidelines, which urge evaluation criteria to be mutually independent. The complex problem of hierarchy construction was simplified by breaking it into levels and arranging them according to hierarchy assigned. Each hierarchy level comprised a number of selection/matching criteria. The top level of the hierarchy represented the final goal and the second level of the hierarchy consisted of eight main outsourcer's selection criteria. The third level of the hierarchy comprised various sub-criteria which influence an organisation's choice for a particular outsourcee candidate. Finally, the bottom level of the hierarchy represented the alternative outsourcing participants (Outsourcee/Outsourcer).

In order to show the practical application of the model, the data that used for calculation, was collected from four UK-based manufacturing companies practising outsourcing. The data collected from the questionnaire survey 2 was used for constructing matrices (*Appendix C* _questionnaire 2). The decision-makers from each of the companies were requested to provide opinions/judgements by answering a pair-wise comparison questionnaire. The judgements are based on a nine-point ratio scale. A nine-point ratio scale was selected in order to assign distinct relative priorities (preferences) to criteria employing pair-wise comparison. The ratio scale varies from two attributes being equally important to each other, to one of the attributes being more extremely important than the other. The decision-makers were requested to provide opinions/judgements using a pair-wise comparison questionnaire.

The decision-maker compares any two criteria or attributes at the same level of hierarchy and provides a numerical value of their importance. It is necessary to have '$n(n-1)/2$' judgements to complete pair-wise comparison for a particular level with 'n' number of criteria. The second half of the comparison matrix is the reciprocal of the judgements above the diagonal of the matrix (Saaty, 1980). The decision-makers assigned the relative score to criteria and sub-criteria according to their importance, which was used in evaluating the priority weights of the alternatives.

A square matrix is formed by arranging attributes/criteria vertically from top to bottom and arranging the same criteria, in the same order, from left to right. All of the diagonal elements of the matrix are '1'. The second half of the comparison matrix is the reciprocal of the judgements above the diagonal of the matrix (Saaty, 1980).

$$V_{Newton} = \begin{bmatrix} \mathbf{1} & 1/4 & 1/2 & 1/5 & 1/3 & 1/4 & 1/4 & 1/5 \\ 4/1 & \mathbf{1} & 1/3 & 1/5 & 1/4 & 1/4 & 1/4 & 1/5 \\ 2/1 & 3/1 & \mathbf{1} & 1/2 & 1/3 & 1/3 & 1/3 & 1/4 \\ 5/1 & 5/1 & 2/1 & \mathbf{1} & 1/5 & 1/5 & 1/4 & 1/5 \\ 3/1 & 4/1 & 3/1 & 5/1 & \mathbf{1} & 1/5 & 1/4 & 1/5 \\ 4/1 & 4/1 & 3/1 & 5/1 & 5/1 & \mathbf{1} & 1/4 & 1/5 \\ 4/1 & 4/1 & 3/1 & 4/1 & 4/1 & 4/1 & \mathbf{1} & 1/4 \\ 5/1 & 5/1 & 4/1 & 5/1 & 5/1 & 5/1 & 4/1 & \mathbf{1} \end{bmatrix} \quad \ldots (5.1)$$

The matrix V_{Newton} shown as expression 5.1 is constructed using the judgements from Newton Engineering. All the columns of the matrix are independently normalised to a sum of one. Then each row of the matrix is averaged to give relative priorities of each criteria under consideration and resulted as a priority weight vector W_{Newton} shown as expression 5.2 (See *Appendix E* for detail). The normalised principal eigenvector of the paired comparison matrix gives the weights of the elements being compared (Saaty and Alexander, 1981).

$$W_{Newton} = [0.0307 \quad 0.0458 \quad 0.0588 \quad 0.0855 \quad 0.1094 \quad 0.1537 \quad 0.1901 \quad 0.3261]^T \quad \ldots (5.2)$$

Similarly, matrices shown as expressions 5.3, 5.4 and 5.5 are constructed using the judgements from London Packaging Limited, Kenth Engineering and Sonic Enterprise.

$$V_{LPg} = \begin{bmatrix} \mathbf{1} & 1/3 & 1/2 & 1/3 & 1/4 & 1/3 & 1/4 & 1/5 \\ 3/1 & \mathbf{1} & 1/3 & 1/2 & 1/3 & 1/3 & 1/4 & 1/4 \\ 2/1 & 3/1 & \mathbf{1} & 1/3 & 1/4 & 1/4 & 1/5 & 1/5 \\ 3/1 & 2/1 & 3/1 & \mathbf{1} & 1/3 & 1/4 & 1/4 & 1/5 \\ 4/1 & 3/1 & 4/1 & 3/1 & \mathbf{1} & 1/3 & 1/4 & 1/5 \\ 3/1 & 3/1 & 4/1 & 4/1 & 3/1 & \mathbf{1} & 1/4 & 1/5 \\ 4/1 & 4/1 & 5/1 & 4/1 & 4/1 & 4/1 & \mathbf{1} & 1/5 \\ 5/1 & 4/1 & 5/1 & 5/1 & 5/1 & 5/1 & 5/1 & \mathbf{1} \end{bmatrix} \quad \ldots (5.3)$$

$$V_{Kenth} = \begin{bmatrix} \mathbf{1} & 1/3 & 1/1 & 1/3 & 1/1 & 1/4 & 1/4 & 1/4 \\ 3/1 & \mathbf{1} & 1/1 & 2/1 & 1/3 & 1/2 & 1/2 & 1/1 \\ 1/1 & 1/1 & \mathbf{1} & 2/1 & 1/3 & 1/2 & 1/2 & 1/1 \\ 3/1 & 1/2 & 1/2 & \mathbf{1} & 1/1 & 1/1 & 1/1 & 1/1 \\ 1/1 & 3/1 & 3/1 & 1/1 & \mathbf{1} & 1/2 & 1/2 & 1/3 \\ 4/1 & 2/1 & 2/1 & 1/1 & 2/1 & \mathbf{1} & 1/3 & 1/1 \\ 4/1 & 2/1 & 2/1 & 1/1 & 2/1 & 3/1 & \mathbf{1} & 1/1 \\ 4/1 & 1/1 & 1/1 & 1/1 & 3/1 & 1/1 & 1/1 & \mathbf{1} \end{bmatrix} \quad \ldots (5.4)$$

$$V_{Sonic} = \begin{bmatrix} \mathbf{1} & 2/1 & 2/1 & 2/1 & 2/1 & 2/1 & 2/1 & 2/1 \\ 1/2 & \mathbf{1} & 1/1 & 1/1 & 1/1 & 1/1 & 1/1 & 1/1 \\ 1/2 & 1/1 & \mathbf{1} & 1/2 & 1/2 & 1/2 & 1/2 & 1/2 \\ 1/2 & 1/1 & 2/1 & \mathbf{1} & 1/1 & 1/1 & 1/1 & 1/1 \\ 1/2 & 1/1 & 2/1 & 1/1 & \mathbf{1} & 2/1 & 2/1 & 2/1 \\ 1/2 & 1/1 & 2/1 & 1/1 & 1/2 & \mathbf{1} & 1/2 & 1/2 \\ 1/2 & 1/1 & 2/1 & 1/1 & 1/2 & 2/1 & \mathbf{1} & 1/1 \\ 1/2 & 1/1 & 2/1 & 1/1 & 1/2 & 2/1 & 1/1 & \mathbf{1} \end{bmatrix} \quad \ldots (5.5)$$

All the matrices expressed as 5.3, 5.4 and 5.5 are normalised and their corresponding resultant priority weight vectors of outsourcee selection criteria weights are expressed as 5.6, 5.7 and 5.8.

$$W_{LPg} = [0.0323 \quad 0.0499 \quad 0.0547 \quad 0.0707 \quad 0.1078 \quad 0.1346 \quad 0.2052 \quad 0.3447]^T \quad \ldots(5.6)$$

$$W_{Kenth} = [0.0518 \quad 0.1103 \quad 0.0984 \quad 0.1139 \quad 0.1250 \quad 0.1488 \quad 0.1974 \quad 0.1545]^T \ldots(5.7)$$

$$W_{Sonic} = [0.2158 \quad 0.1079 \quad 0.0723 \quad 0.1168 \quad 0.1555 \quad 0.0940 \quad 0.1188 \quad 0.1188]^T \ldots(5.8)$$

5.3 CLUSTER CONSTRUCTION

The AHP theory presented by Saaty (1980) was only applicable to survey results from one expert. In order to apply AHP to the survey results from a number of experts, cluster analysis was applied.

Supposing that the required criteria decision vector demanded by the i_{th} outsourcer is represented by W_{pi} and is presented as expression 5.9.

$$W_{pi} = \left(\omega_1^{pi}, \omega_2^{pi}, \ldots, \omega_n^{pi}\right)^T \quad \ldots(5.9)$$

The criteria weight vector assigned to i_{th} supplier (candidate outsourcee) represented as W_{si} and is shown as expression 5.10.

$$W_{si} = \left(\omega_1^{si}, \omega_2^{si}, \ldots, \omega_n^{si}\right)^T \quad \ldots(5.10)$$

The Euclidean norm (distance) between the required criteria weight value vector demanded by the i_{th} outsourcer and the criteria weight value vector assigned to i_{th} supplier (candidate outsourcee) is represented by W_{ps} and shown as equation 5.11.

$$W_{ps} = |W_{pi} - W_{si}| = \sqrt{\left(\omega_1^{pi} - \omega_1^{si}\right)^2 + \left(\omega_2^{pi} - \omega_2^{si}\right)^2 + \cdots + \left(\omega_n^{pi} - \omega_n^{si}\right)^2} \quad \ldots (5.11)$$

For establishing a complete picture, it is appropriate to measure the phase angle difference between the required criteria decision vector, demanded by the outsourcer, and the criteria decision vector assigned to a particular supplier (candidate outsourcee), or between two outsourcing participants, shown as equation 5.12.

$$\cos(\theta)_{ps} = \frac{W_{pi} \cdot W_{si}}{|W_{pi}||W_{si}|} \quad \ldots (5.12)$$

When $W_{ps} = |W_{pi} - W_{si}| = 0$ and $Cos\theta_{ps} = 1$, then the outsourcee is most suitable as the outsourcing participant. Similarly, decision vectors can be clustered together when the Euclidean distance between them is the shortest, and the phase angle difference is the smallest i.e. $W_{ps} = |W_{pi} - W_{si}| \to 0$ and $\cos(\theta)_{ps} \to 1$. If the previous criteria of convergence are achieved, then the vector W_{pi} is identical with the vector W_{si} and a perfect match is achieved.

There are $\emptyset_i$ decision-makers in a cluster that holds i_{th} decision-maker. If the weight of the i_{th} decision-maker is $\propto_i$, then $\propto_i$ is proportional to $\emptyset_i$ i.e., $\propto_1 : \propto_2 : \ldots : \propto_N = \emptyset_1 : \emptyset_2 : \ldots : \emptyset_N$ Mei-yuan *et al*. (2006).

Let the decision-maker clusters be represented by $\phi_1, \phi_2, \phi_3, \ldots \phi_N$ and weight coefficient of the i_{th} decision-maker's cluster is calculated by using the equation 5.13.

$$\alpha_i = \phi_i \Big/ \sum_{i=1}^{N} \phi_i \quad \ldots (5.13)$$

The integrated decision weight is calculated by the weighted average of the decision cluster's priority values shown as equation 5.14.

$$W_i = \sum_{i=1}^{N} \alpha_i \omega_i \quad \ldots (5.14)$$

There were four priority weight vectors W_{Newton} , W_{LPG} , W_{Kenth} and W_{Sonic} calculated in the previous section. In order to merge four vectors into a single priority weight vector (benchmark / standard) cluster analysis is carried out and the detail is as follows:

Assume that the phase angular difference between two decision vectors W_{Newton} and W_{LPG} is represented as $W_{Newton-LPg}$. As a measure of the decision vector convergence, 'phase angle difference' was calculated from 'Cosine' values based on dot product of two vectors. The expressions 5.15 – 5.20 showing the trigonometric function Cosine applied to criteria priority weight vectors, were calculated using equation 5.12.

$$\cos(W_{Newton-LPg}) = 0.9973 \quad \ldots (5.15)$$

$$\cos(W_{Newton-Kenth}) = 0.9007 \quad \ldots (5.16)$$

$$\cos(W_{Newton-Sonic}) = 0.7279 \quad \ldots (5.17)$$

$$\cos(W_{LPg-Kenth}) = 0.8849 \quad \ldots (5.18)$$

$$\cos(W_{LPg-Sonic}) = 0.7134 \quad \ldots (5.19)$$

$$\cos(W_{Kenth-Sonic}) = 0.8590 \quad \ldots (5.20)$$

Two or more decision clusters are merged together when cosine of the phase angle difference between two decision makers approaches to one (Phase angle diffence is closer to zero).

The Phase angle difference between the Newton Equipment and the London Packaging is 4.21^o , between Newton Equipment and Kenth Engineering is 25.74^o and between Kenth Engineering and London Packaging is27.76^o.

On the other hand the Phase angle difference between Kenth Engineering and Sonic Enterprises is 30.80^o , between Newton Equipment and Sonic Enterprises is $43.29^o$and between London Packaging and Sonic Enterprises is 44.49^o.

It can be seen clearly that the phase angle differences amongst Newton Equipment, London Packaging, and Kenth Engineering are smaller compared to Phase angle differeneces amongst Sonic Enterprise and Newton Equipment, London Packaging and Kenth

Engineering. Thus, the Newton Equipment, London Packaging, and Kenth Engineering are grouped into one cluster.

Due to relatively large phase angle difference between the Sonic Enterprise and cluster of Newton Equipment, London Packaging, and Kenth Engineering, the Sonic Enterprise is not mereged with other companies.

In order to test whether the Euclidean (norm) distance provides the same results as that of the phase angle difference. The Euclidean (norm) distance was calculated using equation 5.11. The Eucleadian norm (distance) between two decision maker's vectors shows the difference between two decision makers.

The Eucleadian distance between Newton Equipment and London Packaging is 0.0346, between Newton Equipment and Kenth Engineering is 0.1917 and between Kenth Engineering and London Packaging is 0.2110.

The Eucleadian distance between Kenth Engineering and Sonic Enterprises is 0.1974, between Newton Equipment and Sonic Enterprise is 0.3050 and between London Packaging and Sonic Enterprises is 0.3192.

By observing the Eucleadian distances, it can be noticed that Newton Equipment, London Packaging, and Kenth Engineering have relatively high similarity (difference among them is small) for grouping into one cluster and Sonic Enterprise stands on its own (It defines itself as a cluster).

Let $\emptyset_1$ represents the numbers of decision-makers in a cluster that is occupied by the Newton Equipment and α_1 is the weighted co-efficient. The same way $\emptyset_2$ and α_2 represents London Packaging, $\emptyset_3$ and α_3 represents Kenth Engineering and finaly $\emptyset_4$ and α_4 represent Sonic Enterprise.

The numbers of decision-makers in each cluster are:

$$\phi_1 = \phi_2 = \phi_3 = 3$$

$$\phi_4 = 1$$

The expressions 5.21 and 5.22 show the weighted coefficients of each decision-maker's cluster which is calculated using equation 5.13.

$$\alpha_1 = \alpha_2 = \alpha_3 = \frac{3}{3+3+3+1} = \frac{3}{10} \quad \ldots (5.21)$$

$$\alpha_4 = \frac{1}{10} \quad \ldots (5.22)$$

The final priority weights of the supplier selection criteria are calculated by the weighted average of the decision-makers' cluster's priority values using equation 5.14. The results of the priority weight vector of criteria are listed in Table 5.1.

Criteria	**Priority Weight**
Organisational Environmental and Laws	0.056020
Technology and Manufacturing Ability	0.072590
Financial Operation Ability	0.070800
Reputation	0.092710
Management and Business Professionalism	0.118210
Effective Cost	0.140530
On-Time Delivery	0.189690
Quality	0.259470

Table 5.1: Priority Weights of Outsourcer's Selection Criteria

The Table 5.1 shows that 'Quality' has the highest priority weight and 'Organisational and Evironmental Laws' achieves the lowest priority weight.

5.4 EVALUATION OF PRIORITY WEIGHTS OF SUB-CRITERIA

The priority weights of sub-criteria were also calculated by following the same procedure as criteria. In case of criteria, two methods (cosine and the Eucleadian norm) were used for

grouping the experts in to clusters. The outcome was similar. Now, in case of sub-criteria, only Eucleadian norm (distance) has been used.

5.4.1 ORGANISATIONAL AND ENVIRONMENTAL LAWS

Organisational and Environmental laws are divided into sub-criteria such as 'Outsourcee Understands Business Rules' and 'Intellectual Property Laws'. The matrices constructed from the decision-makers' judgements are shown as expressions 5.23 – 5.26 and their corresponding priority vectors are shown as expressions 5.27 – 5.30.

$$v_{OEL\_Newton} = \begin{matrix} \\ UBL \\ UIPL \end{matrix} \begin{matrix} \begin{bmatrix} UBL & UIPL \end{bmatrix} \\ \begin{bmatrix} 1 & 2 \\ 1/2 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.23)$$

$$v_{OEL\_LPg} = \begin{matrix} \\ UBL \\ UIPL \end{matrix} \begin{matrix} \begin{bmatrix} UBL & UIPL \end{bmatrix} \\ \begin{bmatrix} 1 & 2 \\ 1/2 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.24)$$

$$v_{OEL\_Kenth} = \begin{matrix} \\ UBL \\ UIPL \end{matrix} \begin{matrix} \begin{bmatrix} UBL & UIPL \end{bmatrix} \\ \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.25)$$

$$v_{OEL\_Sonic} = \begin{matrix} \\ UBL \\ UIPL \end{matrix} \begin{matrix} \begin{bmatrix} UBL & UIPL \end{bmatrix} \\ \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.26)$$

The matrices 5.23 – 5.26 are transformed into priority weight vectors through normalisation and are shown as follows:

$$w_{OEL\_Newton} = (0.6667 \quad 0.3333)^T \quad \ldots (5.27)$$

$$w_{OEL\_LPg} = (0.6667 \quad 0.3333)^T \quad \ldots (5.28)$$

$$w_{OEL\_Kenth} = (0.5000 \quad 0.5000)^T \quad \ldots (5.29)$$

$$w_{OEL\_Sonic} = (0.5000 \quad 0.5000)^T \quad \ldots (5.30)$$

The Euclidean distance was calculated using equation 5.11. The difference between the priority weight vectors of Newton Engineering and Kenth Engineering is 0.2357, and the

difference between Newton Engineering and Sonic Enterprise is 0.2357. Whereas, (the Eucleadian norm) difference between the Newton Engineering and the London Packaging is 0.0000 and is relatively small for grouping into one cluster. The difference between the London Packaging and Kenth Engineering is the same and between London Packaging and the Sonic Enterprise is 0.2357. The difference between Kenth Engineering and the Sonic Enterprise is 0.0000 and are grouped into a second cluster.

Let $\emptyset_1$ represents the numbers of decision-makers in a cluster that is occupied by the Newton Equipment and α_1 is the weighted co-efficient. The same way $\emptyset_2$ and α_2 represents London Packaging, $\emptyset_3$ and α_3 Kenth Engineering and $\emptyset_4$ and α_4 represent Sonic Enterprise.

Thus, for Organisational and Environmental Laws, the number of decision-makers in each cluster are $\phi_1 = \phi_2 = 2$ and $\phi_3 = \phi_4 = 2$, the expressions 5.31 and 5.32 show the weighted coefficient of each decision-maker's cluster that is calculated using the equation 5.13.

$$\because \alpha_1 = \alpha_2 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.31)$$

$$\because \alpha_3 = \alpha_4 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.32)$$

The priority weights of sub-criteria are calculated by the weighted average of the decision cluster's priority weights using equation 5.14.

Hence, *Outsourcee understands Business Rules=0.4166, Intellectual Property Laws=0.5834.*

5.4.2 TECHNOLOGY AND MANUFACTURING ABILITY

Technology and Manufacturing Ability is divided into sub-criteria, such as Hardware, Personnel Capability and Process Capability. The matrices constructed from the decision-makers' judgements are shown as expressions 5.33 – 5.36.

$$v_{TMA\_Newton} = \begin{array}{c} \\ HdWr \\ PlCp \\ \Pr Cp \end{array} \begin{bmatrix} HdWr & PlCp & \Pr Cp \\ 1 & 2 & 3 \\ 1/2 & 1 & 1/2 \\ 1/3 & 2 & 1 \end{bmatrix} \quad \ldots (5.33)$$

$$v_{TMA\_LPg} = \begin{array}{c} \\ HdWr \\ PlCp \\ \Pr Cp \end{array} \begin{bmatrix} HdWr & PlCp & \Pr Cp \\ 1 & 4 & 2 \\ 1/4 & 1 & 1 \\ 1/2 & 2 & 1 \end{bmatrix} \quad \ldots (5.34)$$

$$v_{TMA\_Kenth} = \begin{array}{c} \\ HdWr \\ PlCp \\ \Pr Cp \end{array} \begin{bmatrix} HdWr & PlCp & \Pr Cp \\ 1 & 2 & 2 \\ 1/2 & 1 & 1 \\ 1/2 & 1 & 1 \end{bmatrix} \quad \ldots (5.35)$$

$$v_{TMA\_Sonic} = \begin{array}{c} \\ HdWr \\ PlCp \\ \Pr Cp \end{array} \begin{bmatrix} HdWr & PlCp & \Pr Cp \\ 1 & 3 & 3 \\ 1/3 & 1 & 1/2 \\ 1/3 & 2 & 1 \end{bmatrix} \quad \ldots (5.36)$$

The Technology and Manufacturing Ability matrices are normalised to priority weight vectors and are presented as expressions 5.37 – 5.40.

$$w_{TMA\_Newton} = (0.5374 \quad 0.1946 \quad 0.2680)^T \quad \ldots (5.37)$$

$$w_{TMA\_LPg} = (0.5714 \quad 0.1429 \quad 0.2857)^T \quad \ldots (5.38)$$

$$w_{TMA\_Kenth} = (0.5000 \quad 0.2500 \quad 0.2500)^T \quad \ldots (5.39)$$

$$w_{TMA\_Sonic} = (0.5889 \quad 0.1593 \quad 0.2519)^T \quad \ldots (5.40)$$

For cluster analysis, the Euclidean distance was calculated using equation 5.11. The difference between Newton Equipment and Kenth Engineering is 0.0692, between Newton Equipment and Sonic Enterprise is 0.0645 and between Newton Equipment and London Packaging is 0.0644 which is relatively small. It is presented as expression 5.41.

$$|w_{TMA\_Newton} - w_{TMA\_LPg}| < |w_{TMA\_Newton} - w_{TMA\_Kenth}| < |w_{TMA\_LPg} - w_{TMA\_Kenth}| \quad \ldots (5.41)$$

Similarly the difference between London Packaging and Kenth Engineering is 0.1336, and between London Packaging and Sonic Enterprise is 0.0414. The difference between, Kenth Engineering and Sonic Enterprise is 0.1270 that is relatively small and is expressed as expression 5.42.

$$|W_{TMA\_Newton} - W_{TMA\_Sonic}| < |W_{TMA\_Newton} - W_{TMA\_Kenth}| < |W_{TMA\_Kenth} - W_{TMA\_Sonic}| \quad \ldots (5.42)$$

By observing the expressions 5.41 and 5.42, it can be noted that W_{TMA_Newton}, W_{TMA_LPG} and W_{TMA_Sonic} have relatively small difference for grouping as one cluster and W_{TMA_Kenth} stands on its own.

The numbers of the decision-makers in each cluster are:

$$\phi_1 = \phi_2 = \phi_4 = 3$$

$$\phi_3 = 1$$

The expressions 5.43 – 5.44 show the weighted coefficient of each decision-maker's cluster that is calculated using the equation 5.13.

$$\because \alpha_1 = \alpha_2 = \alpha_4 = \frac{3}{3+3+3+1} = \frac{3}{10} \quad \ldots (5.43)$$

$$\alpha_3 = \frac{1}{10} \quad \ldots (5.44)$$

The priority weights of sub-criteria of Technology and Manufacturing Ability is calculated by the weighted average of the decision-makers' cluster's priority weights using equation 5.14.

Hence, *Hardware=0.5593, Personnel Capability=0.1740 and Process Capability=0.2667.*

5.4.3 FINANCIAL OPERATION ABILITY

Financial Operation Ability is divided into sub-criteria such as Financial Stability and Time (Duration) in Business. The priority vectors of the decision-makers' judgements are shown as expressions 5.45 – 5.48.

$$v_{FA\_Newton} = NBcy \begin{matrix} \\ TIB \end{matrix} \begin{matrix} \begin{bmatrix} NBcy & TIB \end{bmatrix} \\ \begin{bmatrix} 1 & 2 \\ \frac{1}{2} & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.45)$$

$$v_{FA\_LPg} = NBcy \begin{matrix} \\ TIB \end{matrix} \begin{matrix} \begin{bmatrix} NBcy & TIB \end{bmatrix} \\ \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.46)$$

$$v_{FA\_Kenth} = NBcy \begin{matrix} \\ TIB \end{matrix} \begin{matrix} \begin{bmatrix} NBcy & TIB \end{bmatrix} \\ \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.47)$$

$$v_{FA\_Sonic} = NBcy \begin{matrix} \\ TIB \end{matrix} \begin{matrix} \begin{bmatrix} NBcy & TIB \end{bmatrix} \\ \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix} \end{matrix} \quad \ldots (5.48)$$

The decision vectors w_{FA_Newton}, w_{FA_LPG}, w_{FA_Kenth} and w_{FA_Sonic} are formed by normalisation of the expert's judgement matrices and are presented as expressions 5.49 – 5.52.

$$w_{FA\_Newton} = (0.6667 \quad 0.3333)^T \quad \ldots (5.49)$$

$$w_{FA\_LPg} = (0.5000 \quad 0.5000)^T \quad \ldots (5.50)$$

$$w_{FA\_Kenth} = (0.5000 \quad 0.5000)^T \quad \ldots (5.51)$$

$$w_{FA\_Sonic} = (0.5000 \quad 0.5000)^T \quad \ldots (5.52)$$

The Euclidean distance was calculated using equation 5.11. According to calculation the difference between the sub-criteria priority weights vectors of Newton Equipment and London Packaging is 0.2357, and the difference between Newton Equipment and Kenth Engineering is 0.2357. The difference between Newton Equipment and Sonic Enterprise is 0.2357. The difference between London Packaging and Kenth Engineering, between London Packaging and Sonic Enterprise and between, Kenth Engineering and Sonic Enterprise is 0.0000.

Since, London Packaging, Kenth Engineering and Sonic Enterprise have relatively high similarity for grouping into one cluster, and Newton Equipment stands on its own.

The numbers of decision-makers in each cluster are:

$\phi_2 = \phi_3 = \phi_4 = 3$,

$\phi_1 = 1$.

The expressions 5.53 and 5.54 show the weighted coefficient of each decision-maker's cluster that is calculated using the equation 5.13.

$$\because \alpha_2 = \alpha_3 = \alpha_4 = \frac{3}{3+3+3+1} = \frac{3}{10} \quad \ldots (5.53)$$

$$\alpha_1 = \frac{1}{10} \quad \ldots (5.54)$$

The sub-criteria priority weight is calculated by the weighted average of the decision cluster's priority weights using equation 5.14.

Hence, *Financial Stability (Not subject to Bankruptcy or receivership) =0.5167, and Time (Duration) in Business =0.483.*

5.4.4 Reputation

The priority weights of sub-criteria of Reputation are calculated and are listed in Table 5.2.

Responsiveness to change	Flexibility to adjust change	Link with a number of low-tier suppliers	Linked Suppliers comply quality Standards	Secure Communication System	Information declaration about linked suppliers	Linked suppliers participate in improvements	Good relationship with linked suppliers
0.0500	**0.1682**	**0.0812**	**0.0969**	**0.1682**	**0.1682**	**0.1244**	**0.1460**

Table 5.2: Priority Weights of Sub-criteria of Reputation

5.4.5 MANAGEMENT AND BUSINESS PROFESSIONALISM

Management and Business Professionalism is divided into sub-criteria such as 'Understanding the Customer's Requirements' and 'Trained Staff for Relationship development'. The matrices constructed from the decision-makers' judgements are shown as expressions 5.55 – 5.58

$$v_{MBP\_Newton} = \begin{matrix} \\ UBR \\ TSCR \end{matrix} \begin{bmatrix} UBR & TSCR \\ 1 & 2 \\ 1/2 & 1 \end{bmatrix} \quad \ldots (5.55)$$

$$v_{MBP\_LPg} = \begin{matrix} \\ UBR \\ TSCR \end{matrix} \begin{bmatrix} UBR & TSCR \\ 1 & 2 \\ 1/2 & 1 \end{bmatrix} \quad \ldots (5.56)$$

$$v_{MBP\_Kenth} = \begin{matrix} \\ UBR \\ TSCR \end{matrix} \begin{bmatrix} UBR & TSCR \\ 1 & 3 \\ 1/3 & 1 \end{bmatrix} \quad \ldots (5.57)$$

$$v_{MBP\_Sonic} = \begin{matrix} \\ UBR \\ TSCR \end{matrix} \begin{bmatrix} UBR & TSCR \\ 1 & 3 \\ 1/3 & 1 \end{bmatrix} \quad \ldots (5.58)$$

The decision vectors calculated in this section are w_{MBP_Newton}, w_{MBP_LPG}, w_{MBP_Kenth} and w_{MBP_Sonic} are shown as expressions 5.59 – 5.62.

$$W_{MBP\_Newton} = (0.7500 \quad 0.2500)^T \quad \ldots (5.59)$$

$$W_{MBP\_LPg} = (0.6667 \quad 0.3333)^T \quad \ldots (5.60)$$

$$W_{MBP\_Kenth} = (0.6667 \quad 0.3333)^T \quad \ldots (5.61)$$

$$W_{MBP\_Sonic} = (0.7500 \quad 0.2500)^T \quad \ldots (5.62)$$

The equation 5.11 is used for calculating Euclidean distance. For management and business professionalism the difference between Newton Equipment and Sonic Enterprise and between London Packaging and Kenth Engineering is 0.0000. The difference between Newton Equipment and London Packaging and between Newton Equipment and Sonic Enterprise is 0.1178.

The Euclidean norm between Newton Equipment and Sonic Enterprise is the minimum, thus have relatively high similarity for grouping into one cluster. Similarly, London Packaging and Kenth Engineering have high similarity and are grouped as a second cluster.

So, the numbers of decision-makers in each cluster are $\phi_1 = \phi_2 = 2$ and $\phi_3 = \phi_4 = 2$. The expressions 5.63 and 5.64 show the weighted coefficient of each decision-maker's cluster and are calculated by using the equation 5.13.

$$\because \alpha_1 = \alpha_2 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.63)$$

$$\because \alpha_3 = \alpha_4 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.64)$$

The integrated decision weight is calculated by the weighted average of the decision maker's cluster's priority values using equation 5.14.

Hence, *Understanding the Customer's Requirements = 0.7084, and Trained Staff for Relationship = 0.2916.*

5.4.6 EFFECTIVE COST

Effective Cost is divided into sub-criteria such as Competitive Cost, Sustainable Cost and Consistent Cost. The matrices constructed from the decision-makers' judgements sub-criteria of Effective Cost are shown as expressions 5.65 – 5.68.

$$v_{CE\_Newton} = \begin{array}{c} \\ CmC \\ SC \\ CCn \end{array} \begin{bmatrix} CmC & SC & CCn \\ 1 & 3 & 3 \\ 1/3 & 1 & 1 \\ 1/3 & 1 & 1 \end{bmatrix} \quad \ldots (5.65)$$

$$v_{CE\_LPg} = \begin{array}{c} \\ CmC \\ SC \\ CCn \end{array} \begin{bmatrix} CmC & SC & CCn \\ 1 & 2 & 1 \\ 1/2 & 1 & 1/2 \\ 1 & 2 & 1 \end{bmatrix} \quad \ldots (5.66)$$

$$v_{CE\_Kenth} = \begin{array}{c} \\ CmC \\ SC \\ CCn \end{array} \begin{bmatrix} CmC & SC & CCn \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad \ldots (5.67)$$

$$v_{CE\_Sonic} = \begin{array}{c} \\ CmC \\ SC \\ CCn \end{array} \begin{bmatrix} CmC & SC & CCn \\ 1 & 3 & 3 \\ 1/3 & 1 & 1/2 \\ 1/3 & 2 & 1 \end{bmatrix} \quad \ldots (5.68)$$

The priority weight vectors obtained from normalisation of matrices structure from decision-makers' judgements are shown as expressions 5.69 – 5.72.

$$w_{CE\_Newton} = (0.6000 \quad 0.2000 \quad 0.2000)^T \quad \ldots (5.69)$$

$$w_{CE\_LPg} = (0.4000 \quad 0.2000 \quad 0.4000)^T \quad \ldots (5.70)$$

$$w_{CE\_Kenth} = (0.3333 \quad 0.3333 \quad 0.3333)^T \quad \ldots (5.71)$$

$$w_{CE\_Sonic} = (0.5889 \quad 0.1593 \quad 0.2519)^T \quad \ldots (5.72)$$

The decision vectors calculated in this section are w_{CE_Newton}, w_{CE_LPG}, w_{CE_Kenth} and w_{CE_Sonic}. According to calculation the difference between Newton Equipment and

London Packaging is 0.1871, and the difference between Newton Equipment and Kenth Engineering is 0.2041. The difference between Newton Equipment and Sonic Enterprise is 0.1058. Similarly the difference between London Packaging and Kenth Engineering is 0.1633, and between London Packaging and Sonic Enterprise is also 0.2908. The difference between, Kenth Engineering and Sonic Enterprise is 0.2690.

By comparing decision vector differences, Newton Equipment and Sonic Enterprise have relatively high similarity for grouping into one cluster. The London Packaging and Kenth Engineering also have high similarity and are grouped as a second cluster. So, numbers of decision-makers in each cluster are $\phi_1 = \phi_4 = 2$ and $\phi_2 = \phi_3 = 2$. The expressions 5.73 and 5.74 show the weighted coefficient of each decision-maker's cluster and are calculated by using the equation 5.13.

$$\because \alpha_1 = \alpha_4 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.73)$$

$$\because \alpha_2 = \alpha_3 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.74)$$

The priority weights of sub-criteria of effective cost are calculated by the weighted average of the decision maker's cluster's priority values shown as equation 5.14.

Hence, *Competitive Cost=0.4806, Sustainable Cost=0.2232 and Consistent Cost=0.2942.*

5.4.7 ON-TIME DELIVERY

On-Time Delivery is divided into sub-criteria such as Delivery Lead Time, Delivery Consistency and Delivery Documentation. The matrices constructed from the decision-makers' judgements sub-criteria of effective cost are shown as expressions 5.75 – 5.78

$$v_{OTD\_Newton} = \begin{array}{c} \\ DLT \\ DC \\ DD \end{array} \begin{array}{c} \begin{array}{ccc} DLT & DC & DD \end{array} \\ \begin{bmatrix} 1 & 1/2 & 1 \\ 2 & 1 & 2 \\ 1 & 1/2 & 1 \end{bmatrix} \end{array} \quad \ldots (5.75)$$

$$v_{OTD\_LPg} = \begin{array}{c} \\ DLT \\ DC \\ DD \end{array} \begin{bmatrix} DLT & DC & DD \\ 1 & 1/2 & 1/2 \\ 2 & 1 & 1 \\ 2 & 1 & 1 \end{bmatrix} \quad \ldots (5.76)$$

$$v_{OTD\_Kenth} = \begin{array}{c} \\ DLT \\ DC \\ DD \end{array} \begin{bmatrix} DLT & DC & DD \\ 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad \ldots (5.77)$$

$$v_{OTD\_Sonic} = \begin{array}{c} \\ DLT \\ DC \\ DD \end{array} \begin{bmatrix} DLT & DC & DD \\ 1 & 1/2 & 2 \\ 2 & 1 & 3 \\ 1/2 & 1/3 & 1 \end{bmatrix} \quad \ldots (5.78)$$

The priority weights vectors w_{OTD_Newton}, w_{OTD_LPG}, w_{OTD_Kenth} and $w_{OTD_{Sonic}}$ of the decision-makers' judgements are shown as expressions 5.79 – 5.82.

$$w_{OTD\_Newton} = (0.2500 \quad 0.5000 \quad 0.2500)^T \quad \ldots (5.79)$$

$$w_{OTD\_LPg} = (0.2000 \quad 0.4000 \quad 0.4000)^T \quad \ldots (5.80)$$

$$w_{OTD\_Kenth} = (0.3333 \quad 0.3333 \quad 0.3333)^T \quad \ldots (5.81)$$

$$w_{OTD\_Sonic} = (0.2973 \quad 0.5390 \quad 0.1638)^T \quad \ldots (5.82)$$

The Euclidean distance was calculated using equation 5.11. The difference between Newton Equipment and London Packaging is 0.1871, and the difference between Newton Equipment and Kenth Engineering is 0.2041. The difference between Newton Equipment and Sonic Enterprise is 0.1058. Similarly the difference between London Packaging and Kenth Engineering is 0.1633, and between London Packaging and Sonic Enterprise is 0.2908. The difference between, Kenth Engineering and Sonic Enterprise is 0.2690.

By comparing the Euclidean (distances) differences it is clear that the Newton Equipment and Sonic Enterprise have relatively high similarity for grouping into a cluster. Similarly London Packaging and Kenth Engineering have high similarity and are grouped as a second cluster. So, numbers of decision-makers in each cluster are $\phi_1 = \phi_4 = 2$ and

$\phi_2 = \phi_3 = 2$. The expressions 5.83 and 5.84 show the weighted coefficient of each decision-maker's cluster, and these are calculated using the equation 5.13.

$$\because \alpha_1 = \alpha_4 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.83)$$

$$\because \alpha_2 = \alpha_3 = \frac{2}{2+2+2+2} = \frac{2}{8} \quad \ldots (5.84)$$

The priority weights of sub-criteria are calculated by the weighted average of the decision maker's cluster's priority values using equation 5.14.

Hence, *Delivery Lead Time=0.2702, Delivery Consistency=0.4430 and Delivery Documentation=0.2868.*

5.4.8 QUALITY

Quality is divided into sub-criteria such as Product Standard, Design Standard and Material Standard. The priority vectors of decision-makers' judgements are shown as expressions 5.85 – 5.88.

$$W_{quality\_Newton} = (0.2500 \quad 0.5000 \quad 0.2500)^T \quad \ldots (5.85)$$

$$W_{quality\_LPg} = (0.2000 \quad 0.4000 \quad 0.4000)^T \quad \ldots (5.86)$$

$$W_{quality\_Kenth} = (0.3333 \quad 0.3333 \quad 0.3333)^T \quad \ldots (5.87)$$

$$W_{quality\_Sonic} = (0.2973 \quad 0.5390 \quad 0.1637)^T \quad \ldots (5.88)$$

The integrated decision weight is calculated by the weighted average of the decision cluster's priority values using equation 5.14.

Hence, *Product Standard=0.5066, Design Standard=0.2734 and Material Standard=0.2200.*

Sub-Criterion	Priority Weight	Sub-Criterion	Priority Weight
Outsourcee Understands Business Rules	0.4166	Intellectual Property Protection Laws	0.5834
Hardware	0.5593	Personnel Capability	0.1740
Process Capability	0.2667		
Not subject to Receivership or Bankruptcy	0.5167	Time (Duration) in Business by Outsourcee	0.4833
Responsiveness to change	0.0500	Flexibility to adjust changes	0.1672
Link with a number of low-tier suppliers	0.0812	Linked suppliers comply quality standard	0.0969
Secure communication system	0.1672	Information declaration about linked suppliers	0.1672
Linked suppliers participate in improvements	0.1244	Good relationship with linked suppliers	0.1460
Understanding the Customer 's Requirements	0.7084	Trained Staff for Relationships Development	0.2916
Competitive Cost	0.4806	Sustainable Cost	0.2232
Consistent Cost	0.2962		
Delivery Lead Time	0.2702	Delivery Consistency	0.4430
Delivery Documentation	0.2868		
Product Standard	0.5066	Design Standard	0.2734
Material Standard	0.2200		

Table 5.3: Priority Weights of Sub-criteria

The Table 5.3 lists priority weights of sub-criteria of outsourcer's selection criteria.

5.5 RESULTS AND DISCUSSIONS

The investigation showed that the results of the survey differed from one company to another. For example, a particular company may consider *Quality* as the number one criterion, while another company may consider *Effective Cost* as number one, and rate *Quality* on a lower position. Therefore, all the survey results were collected into a matrix and a normalised eigenvector of this matrix was calculated. The calculated eigenvector represents the objective order of criteria which resulted from the answers matrix of the companies involved in the survey. This eigenvector represents the priority weight vector of selection criteria.

In this chapter, the priority weights of criteria and sub-criteria are calculated using AHP and CA, which are shown in Figure 5.1. The priority weights are compared with the current decision-maker judgements. For example, in the manufacturing sector *Quality* is normally considered as the most important criterion and the final calculation results validate it. Among the sub-criteria of *quality*, *product standard* scores the highest importance and *material standard* the least importance. These relative importance weightings facilitate decision-makers in choosing the right outsourcee. It does not mean that a manufacturer which has EU product standard capability can be selected as an outsourcee despite its lack of ability to process material to the required EU standards. In this model quality has been defined in terms of *product standard, design standard* and *material standard*. All the quality's sub-criteria must satisfy EU standards. The criteria weighting highlights their relative importance. On a scale from zero to one, the priority weight of *Quality* is 0.2595.

On a scale of zero to one, the sub-criteria of *Quality* weightings are calculated as follows: Product Standard weighting 0.5066, Design Standard weighting 0.2734 and Material Standard weighting 0.2200

On-Time Delivery is the second important criterion in the surveyed priority vector. It has three sub-criteria, among which *delivery consistency* has the highest importance and *delivery lead time* has the least importance. An ideal outsourcee should have the ability to deliver consistently with minimum lead time, and with complete documentation. In reality, an outsourcee's minimum lead time is not useful unless deliveries are consistent and accompanied by the correct delivery documents. In the case of an offshore outsourcee, it may not be possible to get customs clearance and carry out delivery matching without the correct documents. On a scale from zero to one, the priority weight of *On-Time Delivery* is 0.1897. On a scale of zero to one, the sub-criteria of *On-Time Delivery* weightings are calculated as follows:

Delivery Lead Time 0.2702, Delivery Consistency 0.4430 and Delivery Documentation 0.2868

Effective Cost occupies third position in the surveyed priority weight vector. Among its sub-criteria *competitive cost* has the highest importance and *consistent cost* the second. The organisations are after competitive cost rather than cheap cost. In addition, consistent cost is preferred to sustainable cost; however consistent cost is not attainable without sustainable cost. On a scale of zero to one, the priority weight of Effective Cost is 0.1405. On a scale of zero to one, the sub-criteria of *Effective Cost* weightings are calculated as follows:

Competitive Cost 0.4806, Sustainable Cost 0.2232 and Cost Consistency 0.2962

Management and Business Professionalism is the fourth criterion in the surveyed priority weight vector. Understanding customer requirements bears higher priority weight than having trained staff for relationship development. It is essential to have experienced staff to understand customer requirements. Professionalism of an organisation is related to the qualification and experience of the staff. An outsourcee who has trained staff, or has a training programme for staff for understanding customer/market requirements is considered most suitable. On a scale of zero to one, the priority weight of Management and Business Professionalism is 0.1182. Similarly, on a scale of zero to one, the sub-criteria of *Management and Business Professionalism* weightings are calculated as follows:

Understanding the Customer's Requirement 0.7084,
Trained Staff for Relationship Development 0.2916

Reputation is the fifth criteria in the survey priority weight vector. In order to reduce the vagueness, reputation is deconstructed into eight sub-criteria; *flexibility to adjust changes*, *secure communication and Information declaration about linked suppliers* have the highest priority weights, and *responsiveness to change* scores the lowest priority weight. A reputable outsourcee is flexible and responsive to change, has a secure communication system and informs about all the linked companies (customers and suppliers). On a scale from zero to one, the priority weight of Reputation is 0.0927.
On a scale of zero to one, the sub-criteria of *Reputation* weightings are calculated as follows:

Responsiveness to Change 0.0500, Flexibility to Adjust Changes 0.1672, Link with a Number of Low-Tier Suppliers 0.0812, Linked Suppliers Comply Quality Standards 0.0969, Secure Communication System 0.1672, Information Declaration about Linked Suppliers 0.1672, Linked Suppliers Participate in Improvements 0.1224 and Good Relationship with Linked Suppliers 0.1460

The criterion *Technology and Manufacturing Ability* is the sixth on the importance list in the surveyed priority weight vector. Among its three sub-criteria, *hardware* has the highest priority weight and *personnel capability* the lowest priority weight. A manufacturer, despite having hardware and process papability, cannot possess manufacturing ability without personnel capability. The initial outsourcee search was carried out on the basis of manufacturing capability. When assigning priority weights the outcome is different. On a scale of zero to one, the priority weight of *Technology and Manufacturing Ability* is 0.0726.

On a scale of zero to one, the sub-criteria of *Technology and Manufacturing Ability* weightings are calculated as follows:

Hardware 0.5593, Personnel Capability 0.1740 and Process Capability 0.2667

The *Financial Operation Ability* is the seventh-most important in the surveyed priority weight vector. The sub-criterion *not subjected to receivership or bankruptcy* has higher priority weight than the sub-criterion *time (Duration) in business by outsourcee*. Financially, the most stable manufacturer may not be a suitable outsourcee. A financially stable manufacturer may not require external investments. In this regard, a suitable outsourcee is the one who has been in business for more than three years and not subjected to receivership or bankruptcy. On a scale of zero to one, the priority weight of *Financial Operation Ability* is 0.0708.

On a scale of zero to one, the sub-criteria of *Financial Operation Ability* weightings are calculated as follows:

Not Subjected to Receivership or Bankruptcy 0.5167,

Time (Duration) in Business by Outsourcee 0.4833

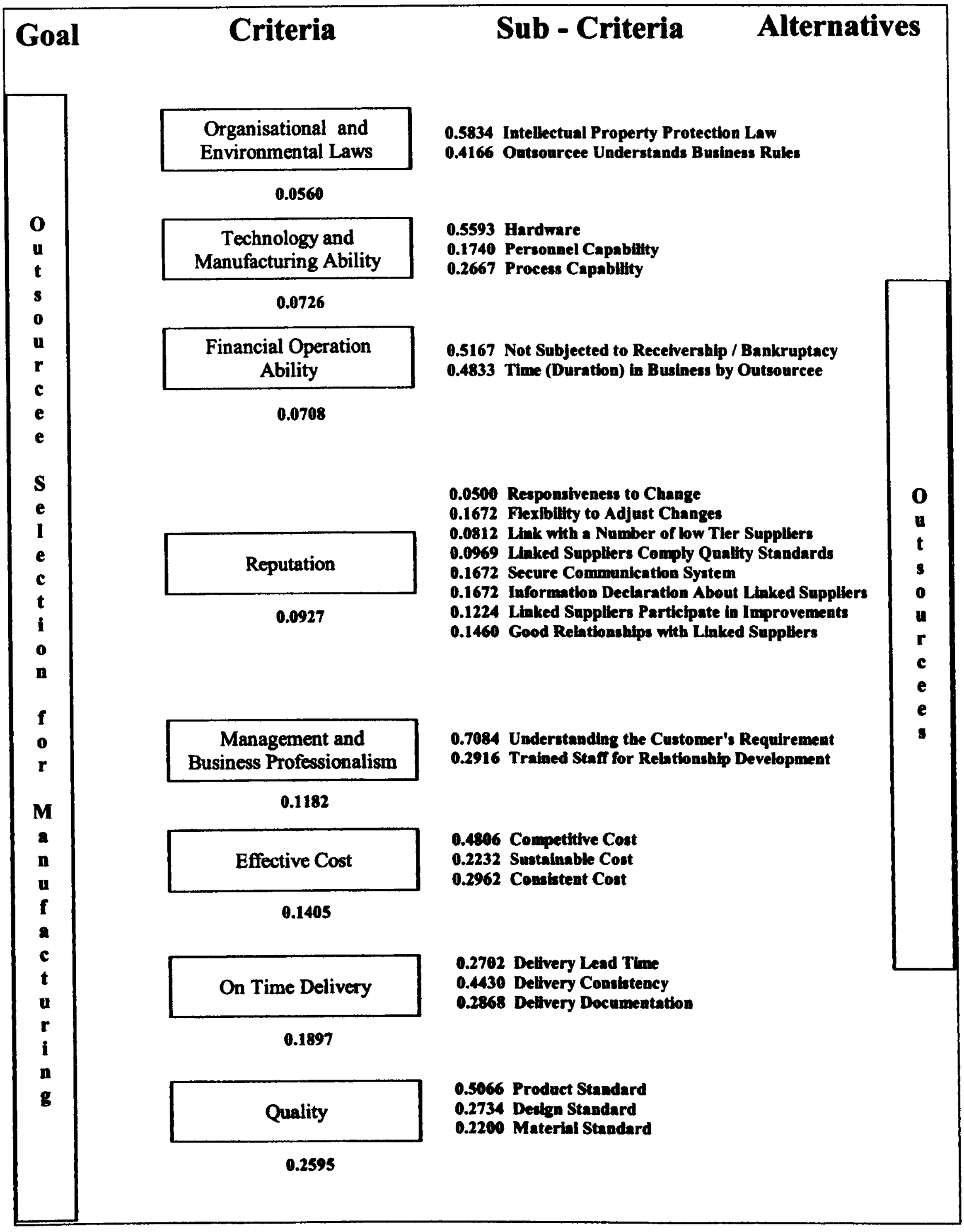

Figure 5.1: The Weighted Hierarchy Structure for Outsourcee Selection

Organisational Environmental and Laws is the eighth criterion in the surveyed priority weight vector. It evaluates an organisation's capability in understanding intellectual property law and business rules. A manufacturer, having all the necessary capabilities to manufacture a product, may not be selected as an outsourcee if it is not practising intellectual property and business laws. On a scale from zero to one, the priority weight of *Organisational Environmental and Laws* is 0.0560.

On a scale of zero to one the sub-criteria of *Organisational Environmental and Laws* weightings are calculated as follows:

Intellectual Property Protection Laws 0.5834,
Outsourcee Understands Business Rules 0.4166

5.6 CONCLUSIONS

In this chapter, the analytical hierarchy process, developed by Saaty (Saaty, 1990) applicable for ranking, assigning priorities and decision making based on single respondent is considered. However, this method on its own can not be used for group decision analysis. The AHP method can be enhanced to include group decision analysis when combined with CA as proposed by Mei-yuan *et al.* (2006). These authors have applied the AHP-CA model for the outsourcing operations in software industry where the cluster analysis is carried out by using trigonometric cosine function that was derived from the dot product of two vectors. The priority weight vectors having cosine values close to one were grouped into one cluster.

In this work the AHP-CA model is further developed by introducing Eucleadian norm for efficient grouping of the priorty weight vectors into clusters. The priority weight vectors having the smallest Eucleadian norm (distance) are grouped into clusters. The Eucleadian norm (distance) defines the difference between priority weights vectors of two experts. It requires less calculations compared to cosine trigonometric function (phase angle difference). The calculations of Eucleadian norm (distance) are relatively simpler and quicker.

The results of cluster analysis using trigonometric function cosine and Eucleadian norm are compareable to cluster the same companies into groups. The application of both techniques for clustering gives comparable results although one technique (Eucleadian norm) is quicker and requires fewer calculations than the other technique (cosine).

By carrying out this study, it has been discovered that for outsourcing in the small and medium sized manufacturing companies, decision-makers allot the highest importance to quality and the least to organisational Environmental and laws. Modifications are recommended according to types of products manufactured, locations of outsourcing participants and relationships between outsourcing participants. The Analytical Hierarchy Process (AHP) and Cluster Analysis (CA) are proved suitable methods for integrating qualitative and quantitative criteria in the manufacturing sector. It was also discovered that an AHP-CA model makes the outsourcing participant-selection process transparent.

Chapter 6

SELECTION OF OUTSOURCEE (SUPPLIER): A CASE STUDY OF TOTALLI SRL

6.1 INTRODUCTION

In this chapter, the outsourcee selection model is applied to Totalli SRL (European-based manufacturing company established in 2004) as a case study for selection of a suitable outsourcee. The model comprises the Analytical Hierarchy Process (AHP), Cluster Analysis (CA) (applied in chapter 5 for evaluating the priority weights of outsourcee selection criteria and sub-criteria) and criteria scoring (S) of outsourcee.

The outsourcee selection performed in the initial stage by the manager of the company, using empirical methods, was re-run using AHP, CA and criteria scoring (S) of outsourcee. The results were compared and found to be a perfect match. However, the developed method is consistent, faster and objective.

Basically, the procedure starts by attributing ranking scores to each selection criterion, according to the ability of each candidate outsourcee. The priority weights of each criterion and sub-criterion are then multiplied by corresponding criteria scoring and the results are summed to a final score. The outsourcee that achieves the highest total score in the model may be considered the most suitable.

6.2 BACKGROUND OF TOTALLI SRL

The objective of Totalli SRL is to become a reputable player in its local market and expand its business nationally as part of its strategic planning. Having achieved a great share of its local market business, Totalli SRL is offering after-sales service and maintenance to other organisations as a supplier (external service, repair and maintenance provider). In order to expand its activities, Totalli SRL decided to outsource in 2006-2007. Totalli SRL acquired outsourcing expertise from Newton Equipment, who have been outsourcing for over a

decade. Considering the previous experience of Newton Equipment, outsourcing was considered a solution to the decline in profit of Totalli SRL.

The management of Totalli SRL performed analysis of its competitors and products. First the right products (Motor-cycles, mopeds and parts) were identified; secondly the products specifications required for outsourcing. Then the company searched, using empirical methods, for the most appropriate outsourcee in order to fulfil the demand of the company.

Identification data for TOTALLI SRL.

Company Name	TOTALLI SRL
Fiscal Code	1359992
Registry No.	J29/2573/1992
Comments	

About TOTALLI SRL - company, products, services

Localization of TOTALLI SRL - contact information.

	County	PRAHOVA
	City/District	PLOIESTI
	Address	STR. ROMANA 55 C*****
	Phone	-
Main	Fax	-
	Mobile	0788-704***** 0744-908*****
	Email	-
	Contact Persons:	ID*****
Web Address	-	

Main activity domains

NACE Code	45*****
Activity	Sale,*****
Activity	This class includes:

Year	Turnover (EUR)	Graphic	Profit (EUR)	Graphic	Employees	Graphic
2008	302*****		102*****			
2007	406*****		727*****			
2006	101*****		-12*****		1*****	
2005	247*****		-71*****		1*****	

Statistic Info

Shareholders	3*****
Administrators	2*****
Subsidiaries	0*****
Branches	7*****

Figure 6.1 Financial History of Totalli SRL

Figure 6.1 illustrates the improvement in the company performances after adopting outsourcing. The results emphasise the fact that the decision to outsource was profitable.

Furthermore, even in the current recession when the product sales are lower, the company is performing well by readjusting the imports towards product parts and involving more resources into servicing.

6.3 CRITERIA SCORING

The relative priority weight vector *W* of surveyed criteria reflects the market in which the company would be operating. The relative priority weights ω_i of criteria shows the overall picture of what is needed to be achieved as reported by the respondents (experts). However, when selecting the outsourcee for a specific company, the particular criteria ranking of the company have to be considered. Therefore, in the selection process of the most appropriate outsourcee, three elements has to be considered; the previously defined 'vector *W* of important criteria resulted from the information analysis of literature survey, questionnaire and interviews', 'the specific criteria ranking (scoring) *S* identified by a particular outsourcer company' and 'the fulfilment of both general criteria (business / market) and specific criteria (outsourcer company) by the potential outsourcees'. In order to satisfy 'relative priority weight vector *W* of important criteria' and 'the specific criteria ranking (scoring) *S* of the companies', the 'snapshot vector components (relative priority weights ω_i of criteria)' has to be tuned with the 'specific company criteria (specific criteria ranking scoring *S*)'. For example, the survey results may indicate that for the market/bussiness quality has the highest ranking. But the specific company may rank the quality lower than price. In this case, the assessment of the potential outsourcee has to be made using a combination of the quality ranking in the general market (ω_i), together with the specific ranking of the particular company which is outsourcing (*S*). The detail of how to assign criteria scoring value for a particular outsourcee (supplier) is given as follows:

Each of the outsourcee selection criteria is assigned a score from 0 to 10, according to the capability of a supplier (outsourcee). For example, in order to assess quality, Totalli SRL recommeneded assigning an outsourcee a score of 10 for conforming ISO or European standards, 7 for American standards and 5 for Chinese standards and 0 for not having or declaring any standard. (For illustration see *Appendix F*)

The 'On Time Delivery' is scaled from 0 to10; 0 when a company does not have the ability to deliver on time and 10 for having the best ability to deliver on time. The 'Effective Cost' is also scaled from 0 to 10; 0 when a supplier is offering a cost that is competitive and is not sustainable over a period of time and 10 for offering a cost that is competitive and is also sustainable over a period of time. The 'Organisational and Environmental Laws' is also scaled from 0 to 10; 10 when a company have been abiding origanisational and business laws to the best of their ability and 0 otherwise.

The 'Technology and Manufacturing Ability' encompasses the hardware, personnel capability and process capability. For selecting an outsourcee 'Technology and Manufacturing Ability' is scaled from 0 to 10; 0 for not having the 'Technology and Manufacturing Ability' and 10 for having the best ability. Like anyother criteria 'Management and Business Professionalism', is also scaled from 0 to 10; 0 for not having the ability and 10 for having the best 'Management and Business Proessionalism Ability'. The criterion 'Financial Operation Ability' evaluates an outsourcee's financial stability and professional accreditation of its accounting staff. It is also scaled from 0 to 10; 0 for not having the ability and 10 for having the best ability. Reputation identifies an outsourcee's ability for completing a contract and its acknowledgement in the community it operates. Similar to other criteria, it is also scaled from 0 to 10; 0 for not having the ability and 10 for the best reputation.

6.4 OUTSOURCEE SELECTION

Selection of a suitable supplier (outsourcee) can help a firm to improve its operations (Wang and Chen, 2007). The proposed outsourcee selection model was applied to rank the suppliers in a logical order according to their total priority (importance) weights, which are calculated from their criteria/sub-criteria weights. Each outsourcee is assessed by employing eight criteria and their twenty-six sub-criteria.

As a test case, the model has been applied to Totalli SRL in order to select an outsourcee based in China. For illustration, the model is applied to compare four (candidate outsourcee) suppliers. The abbreviations of all the criteria, sub-criteria and their corresponding scores, which are used in the formulae/expressions, are listed in 'Notations'. Total outsourcee priority weights are evaluated using equation 6.1.

$$Total\ Priority\ Weight = \sum_{i=1}^{8} \omega_i^c \times \left(\sum_{j=1}^{ns} (\omega_{ij}^{sc} \times S_{kij})\right) \quad \ldots (6.1)$$

Where

ω_i^c= Priority weight of criterion

i= Criterion's number (i = 1,2, ...,8)

ω_{ij}^{sc}= Priority weight of sub-criterion

j= Number of sub-criterion (j = 1,2, ... ns; j $\in I$)

S= Outsourcee's ranking score

k= Candidate outsourcee's number ($k = 1,2, \ldots m; k \in I$)

'ns' is the total number of sub-criteria for a certain criterion. The numbers of sub-criteria vary from two to eight for a particular criterion in the given formulated model, whereas 'm' is the total number of outsourcee candidate applicants.

The set of values of 'k'are assumed as follows:

Dafier = SUPD $k = 1$, for Kinroad = SUPK $k = 2$, for WUXI = SUPW $k = 3$ and for Baoying = SUPB $k = 4$

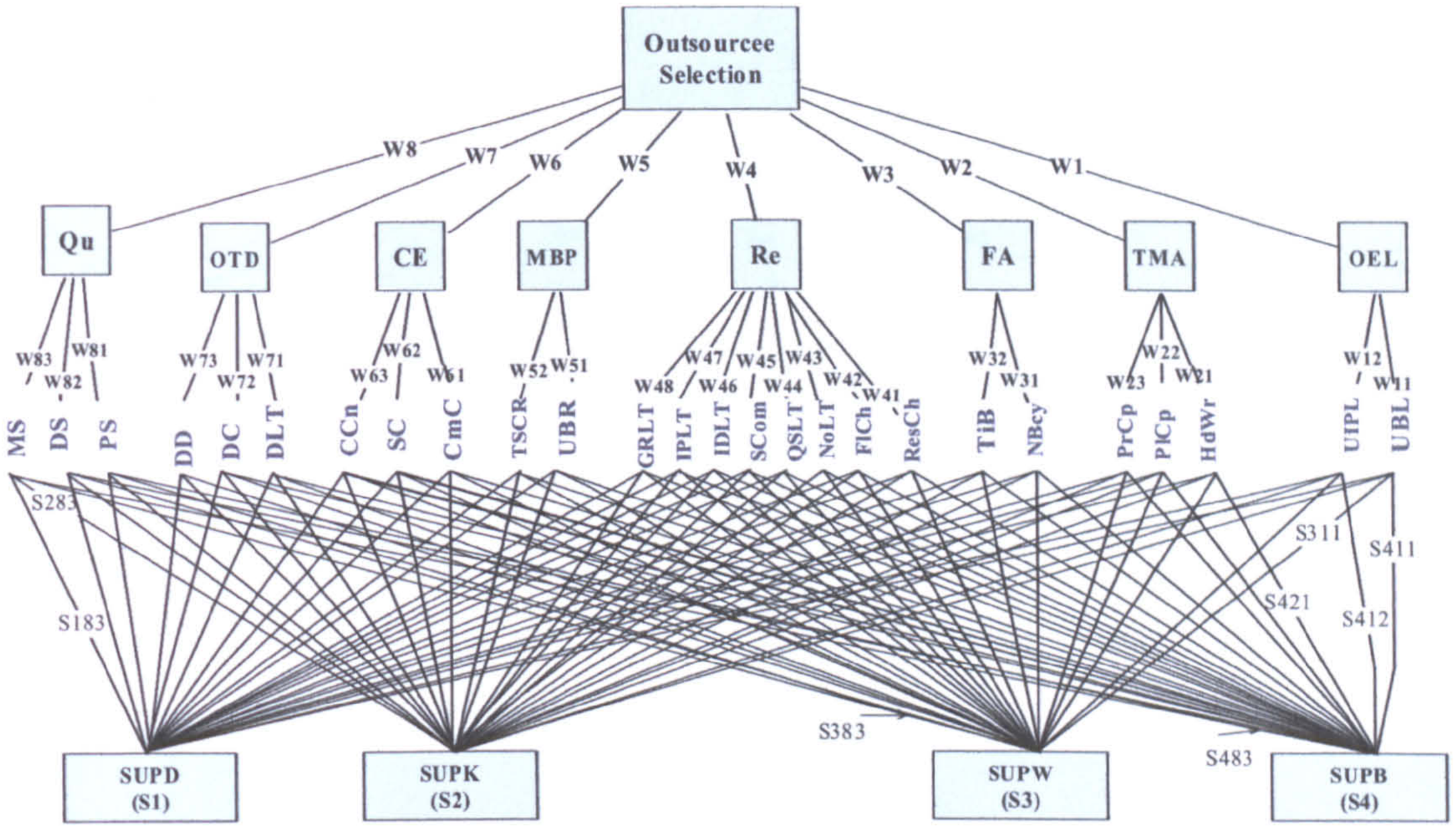

Figure 6.2 Criteria, Sub-criteria for Evaluating Outsourcing Participant (Joint)

Figure 6.2 shows the the four layers of the outsourcee selection hierarchy process. The top layer represents the goal/objective. The second and third hierarchy layers represent outsourcee selection criteria and sub-criteria, respectively. The fourth layer shows four shortlisted candidate outsourcees: SUPD, SUPK, SUPW and SUPB. Figure 6.2 displays 8 criteria and 26 sub-criteria connections, corresponding to each outsourcee. In order to clarify, Figure 6.2 is re-constructed for one candidate outsourcee, in which the hierarchy level 1, level 2 and level 3 are common, whereas level 4 is distinct and shows only one outsourcee. The Figure 6.3 shows the SUPD's priority weight evaluation components.

In order to perform the calculations, the equation 6.1 is expanded to expression 6.2 and the numerical calculation is illustrated in expression 6.3 for SUPD. Similarly, the expressions 6.4 and 6.5 show the numerical calculations for SUPK and SUPW and the expression 6.6 for SUPB.

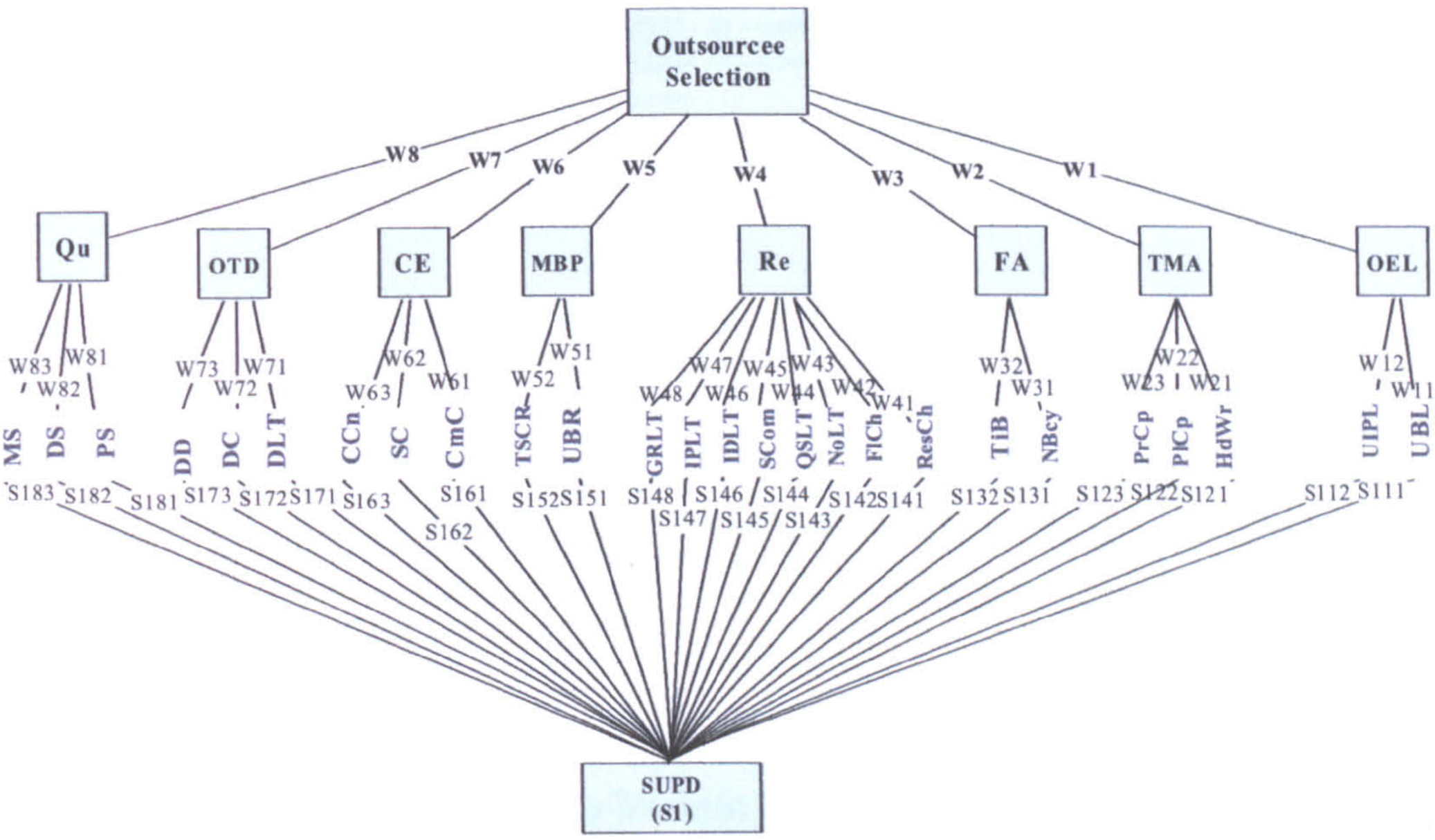

Figure 6.3 Criteria, Sub-criteria for Evaluating Outsourcing Participant (SUPD)

$$\text{SUPD (S1)} = \begin{aligned} & W_1[w_{11}\times S_{111}+w_{12}\times S_{112}]+W_2[w_{21}\times S_{121}+w_{22}\times S_{122}+w_{23}\times S_{123}]+W_3[w_{31}\times S_{131}+w_{32}\times S_{132}]+ \\ & W_4[w_{41}\times S_{141}+w_{42}\times S_{142}+w_{43}\times S_{143}+w_{44}\times S_{144}+w_{45}\times S_{145}+w_{46}\times S_{146}+w_{47}\times S_{147}+w_{48}\times S_{148}]+ \\ & W_5[w_{51}\times S_{151}+w_{52}\times S_{152}]+W_6[w_{61}\times S_{161}+w_{62}\times S_{162}+w_{63}\times S_{163}]+W_7[w_{71}\times S_{171}+w_{72}\times S_{172}+w_{73}\times S_{173}]+ \\ & W_8[w_{81}\times S_{181}+w_{82}\times S_{182}+w_{83}\times S_{183}] \end{aligned} \quad \ldots (6.2)$$

$$\begin{aligned} & 0.0560\times[0.5834\times10+0.4166\times10]+0.0726\times[0.5593\times10+0.1740\times10+0.2667\times10]+0.0708\times[0.5167\times10+0.4833\times6]+ \\ & 0.0927\times[0.0500\times5+0.1672\times0+0.0812\times10+0.0969\times5+0.1672\times0+0.1672\times10+0.1224\times0+0.1460\times0]+ \\ & 0.1182\times[0.7084\times10+0.2916\times10]+0.1405\times[0.4806\times7+0.2232\times0+0.2962\times0]+0.1897[0.2702\times5+0.4430\times0+0.2868\times10]+ \\ & 0.2595\times[0.5066\times10+0.2734\times10+0.2200\times7]=7.0342 \end{aligned} \quad \ldots (6.3)$$

Total Priority Weight of SUPD = 7.0342

$$\begin{aligned} \text{SUPK (S2)} = \; & 0.0560\times[0.5834\times9+0.4166\times9]+0.0726\times[0.5593\times10+0.1740\times8+0.2667\times10] \\ & +0.0708\times[0.5167\times10+0.4833\times7]+ \\ & 0.0927\times\begin{bmatrix}0.0500\times0+0.1672\times0+0.0812\times10+0.0969\times5+\\0.1672\times0+0.1672\times10+0.1224\times0+0.1460\times0\end{bmatrix}+ \\ & 0.1182\times[0.7084\times7+0.2916\times7]+0.1405\times[0.4806\times10+0.2232\times0+0.2962\times0] \\ & +0.1897[0.2702\times5+0.4430\times0+0.2868\times10]+ \\ & 0.2595\times[0.5066\times10+0.2734\times7+0.2200\times7]=6.5991 \end{aligned} \quad \ldots (6.4)$$

Total Priority Weight of SUPK = 6.5991

$$\text{SUPW (S3)} = \begin{aligned} &0.0560 \times [0.5834 \times 10 + 0.4166 \times 10] + 0.0726 \times [0.5593 \times 10 + 0.1740 \times 8 + 0.2667 \times 10] \\ &+ 0.0708 \times [0.5167 \times 10 + 0.4833 \times 10] + \\ &0.0927 \times \begin{bmatrix} 0.0500 \times 0 + 0.1672 \times 0 + 0.0812 \times 10 + 0.0969 \times 5 + \\ 0.1672 \times 0 + 0.1672 \times 10 + 0.1224 \times 0 + 0.1460 \times 0 \end{bmatrix} + \\ &0.1182 \times [0.7084 \times 10 + 0.2916 \times 5] + 0.1405 \times \\ &[0.4806 \times 5 + 0.2232 \times 0 + 0.2962 \times 0] + 0.1897[0.2702 \times 5 + 0.4430 \times 0 + 0.2868 \times 10] + \\ &0.2595 \times [0.5066 \times 10 + 0.2734 \times 5 + 0.2200 \times 5] = 6.3464 \end{aligned} \quad \ldots (6.5)$$

Total Priority Weight of SUPW= 6.3464

$$\text{SUPB (S4)} = \begin{aligned} &0.0560 \times [0.5834 \times 9 + 0.4166 \times 10] + 0.0726 \times [0.5593 \times 8 + 0.1740 \times 7 + 0.2667 \times 10] \\ &+ 0.0708 \times [0.5167 \times 10 + 0.4833 \times 3] + \\ &0.0927 \times \begin{bmatrix} 0.0500 \times 0 + 0.1672 \times 0 + 0.0812 \times 10 + 0.0969 \times 5 + 0.1672 \times 0 + \\ 0.1672 \times 10 + 0.1224 \times 0 + 0.1460 \times 0 \end{bmatrix} + \\ &0.1182 \times [0.7084 \times 10 + 0.2916 \times 5] + 0.1405 \times [0.4806 \times 6 + 0.2232 \times 0 + 0.2962 \times 0] + \\ &0.1897[0.2702 \times 5 + 0.4430 \times 0 + 0.2868 \times 10] + \\ &0.2595 \times [0.5066 \times 5 + 0.2734 \times 5 + 0.2200 \times 5] = 5.3905 \end{aligned} \quad \ldots (6.6)$$

Total Priority Weight of SUPB = 5.3505

6.5 RESULTS AND DISCUSSIONS

The priority weights of selection criteria for SUPB, SUPW, SUPK and SUPD are tabulated in Table 6.1. According to the 'Organisational and Environmental Laws' criterion, SUPK achieves the lowest score while both SUPW and SUPD achieve the highest score. When assessing supplier companies according to 'Technology and Manufacturing Ability', it is found that SUPB is the least suitable, and SUPD is the most suitable with the highest score.

From 'Financial Operation Ability' criteria, SUPW is the most stable and SUPB is the least stable. According to 'Financial Operation Ability' priority weight SUPD has moderate financial stability. It needs investment in order to sustain its activities. Therefore, for a suitable outsourcee, having moderate 'Financial Operation Ability' is a positive point.

SUPD achieves the highest 'Reputation' priority weight. When analysing sub-criteria of 'Reputation' it is highlighted that a suitable company is flexible, responsive to change and linked with a number of low-tier suppliers. The linked suppliers follow quality standards, labour laws and business rules. The same way according to 'Management and Business Professionalism', SUPD achieves the highest score and SUPK the lowest.

The criterion 'Effective Cost' evaluates the capability of an organisation to manufacture a product at a competitive cost that is consistent and sustainable. From the 'Effective Cost' perspective, SUPK is most suitable and SUPD is the second-best choice. But, when comparing companies from the 'Quality' point of view, SUPD manufactures better quality than SUPK. On account of the overall score, SUPD is the first choice and SUPK is the second choice as candidate outsourcee for Totalli SRL.

Criteria	SUPB	SUPW	SUPK	SUPD
Organisational Environmental and Laws	0.5273	0.5600	0.5040	0.5600
Technology and Manufacturing Ability	0.6069	0.7007	0.7007	0.7260
Financial Operation Ability	0.4685	0.7080	0.6053	0.5711
Reputation	0.2752	0.2752	0.2752	0.2984
Management and Business Professionalism	1.0097	1.0097	0.8274	1.1820
Effective Cost	0.4051	0.3376	0.6752	0.4727
On-Time Delivery	0.8003	0.8003	0.8003	0.8003
Quality	1.2975	1.9548	2.2109	2.4237
Total:	5.3905	6.3464	6.5991	7.0342

Table 6.1 List of Supplier (Outsourcee) Comparison

Following the discussions with the managers of Totalli SRL and Newton Equipment, it was found that the appropriate supplier may not be the best in all the capabilities required by the company. For example, a manufacturer who is the best in all disciplines may not need any other company as outsourcing participant because of financial soundness. There could be other possibilities that the manufacturer could be planning to develop its own sales subsideries abroad or the manufacturer is not ready to enter a bounded contract.

The proposed model ranks the candidate suppliers accoding to their capabilities. The final decision depends on whether both outsourcer and outsourcee agree to join as outsourcing participants. There is a possiblilty that a supplier who scores the highest marks ccording to the model, may not want to work with the company. Then according to the list the second best could be considered as the suitable choice for outsourcing participation.

6.6 CONCLUSIONS

The AHP-CA and criteria scoring model has been applied successfully for matching a particular outsourcer with the best potential outsourcee. A real manufacturing company, Totalli SRL was selected in order to compare the results obtained by empirical methods by this company and the results generated by the proposed model. Totalli SRL initially drafted a list of Chinese companies as potential partners for outsourcing. Basically, the procedure starts by attributing ranking scores to each selection criterion, according to the ability of each candidate outsourcee.

The previously calculated relative priority weight vector of the market surveyed criteria reflects the market in which the company would be operating. The relative priority weights of criteria shows the overall picture of what is needed to be achieved as reported by the respondents (managers). However, when selecting the outsourcee for a specific company, the particular criteria ranking of the company were considered. Therefore, in the selection process of the most appropriate outsourcee, three elements were considered; the previously defined priority weight vector of important criteria resulted from the information analysis of literature survey, questionnaire and interviews', 'the specific criteria scoring identified by a particular outsourcer company' and 'the fulfilment of both general criteria for business / market and specific criteria for outsourcer by the potential outsourcees'. In order to satisfy 'relative priority weight vector of important criteria' and 'the specific criteria scoring of the companies', the 'snapshot vector components (relative priority weights of criteria)' were tuned with the 'specific company criteria'.

The priority weights of each criterion and sub-criterion are then multiplied by corresponding criteria scoring and the results are summed to a final score. The outsourcee that achieves the highest total score in the model may be considered the most suitable. The validation of the model consisted of the comparison of the results obtained by using the AHP-CA and criteria scoring model to the results obtained by the empirical method. The AHP-CA and criteria scoring model led to the same results as empirical method, this indicates that the proposed model is right and effective. Furthermore, the model also ranks candidate outsourcees in addition to selecting the most suitable supplier. In conclusion it was proven that the developed method is consistent, faster and objective.

Chapter 7

DEVELOPMENT OF A MANUFACTURING LEVEL AGREEMENT FOR OUTSOURCING

7.1 INTRODUCTION

This chapter explains how to draw up and implement a manufacturing level agreement (contract) for the outsourcing of manufacturing operations. The important factors, which are required to develop a comprehensive contract, are discussed in this chapter. The stages of outsourcing are included, beginning from the first transaction and to the end of the specified contract period and in the event of early termination of the contract, due to unforeseen circumstances. The chapter starts with benchmarking and follows with a Manufacturing Level Agreement (MLA).

From literature survey it was understood that one of the outsourcing problems was due to the fact that the contracts have not addressed the issues such as the effect of non-performance, penalties, baseline measures, contract length and flexibility to incorporate any changes. Tafti (2005) highlighted the risk factors associated due to outsourcing contract i.e., loss of privacy and security, decision process is not defined, outsourcing scope, cost allocation and loss of expertise. Thus there was a need to formulate a model for setting up a procedure for drawing and implementing a contract. In case of outsourcing of manufacturing, the contract was called as manufacturing level agreement.

The first draft was prepared based on published information. The draft was presented to the managing director of Newton Equipment and chief executive of Sonic Enterprise for feedback. The feedback received was incorporated in order to refine the model. It was presented to an experienced solicitor for legal opinion and suggestions were incorporated. Finally, the model was presented to Totalli SRL. The manager of Totalli SRL acknowleged that the procedure is useful and the company will consider it next time when drawing a contract.

7.2 ASSESSMENT OF OUTSOURCING

After starting the outsourcing operation, it was important to select an appropriate tool for assessing outsourcing operations. A number of outsourcing assessment tools were proposed, including: 'Outsourcing Time Measurement Model', 'Outsourcing Cycle Effectiveness (OCE)' and 'Outsourcing Determinant Index (ODI)'. Kaplan *et al.* (1996) expressed manufacturing cycle effectiveness as the ratio of the processing time to the throughput time. By following Kaplan's example, an expression has been developed for outsourcing operations, called outsourcing cycle effectiveness.

The outsourcing cycle effectiveness (OCE) is shown as expression 7.1:

$$OCE = \frac{\textbf{\textit{Manufacturing Time through outsourcing}}}{\textbf{\textit{Total Outsourcing Cycle Time}}} \quad \ldots (7.1)$$

Total time for the complete cycle from 'Order request preparation' to the 'Invoice payment' $= t_{oyc}$ = *Time for order request preparation + Time for communication + Time for order processing + Time for preparing delivery note + Time required for delivery + Time to do delivery matching + Time required for invoice preparation + Time required for invoice matching +Time for money transfer*

Koong *et al.* (2007) developed the 'Outsourcing Determinant Index' (ODI) to evaluate outsourcing versus in-house services, and various outsourcing suppliers for information technology (IT). The ODI was modified for outsourcing of small and medium sized manufacturing companies. There are four factors that influence outsourcing activities: Outsourcer Characteristics (*Resources, Strategy, Technology, Environmental, Quality, Cost, Delivery, Flexibility and Capacity Utilisation*), Outsourcee Characteristics (*Resources, Strategy, Technology, Environmental, Quality, Cost, Delivery, Flexibility, Capacity Utilisation*), Communication System (*Procedure, Personnel, Data, Software, Hardware, Quality, Cost, Delivery, Flexibility, Capacity Utilisation*) and Delivery System (*Procedure, Personnel, Data, Software, Hardware, Quality, Cost, Delivery, Flexibility, Capacity Utilisation*).

The ODI is implemented in three steps.

Step1: The relative importance of each of the determinant variables is rated by experts based on a total weight of one hundred points.

Step 2: The total weight is evaluated respectively in terms of each determinant variable for each period. Outsourcing performance is rated using a five-point scale with 5 = full preference and 1 = least preference.

Step 3: The weight obtained from the determinants in step 1 and the score obtained in step 2 are multiplied to obtain the weighted score of the outsourcing for each period. The sum of the weighted score is the total weighted score. If the total weighted score of the period 2 is greater than the period 1, it shows there has been an improvement in the outsourcing system.

7.3 BENCHMARKING

Benchmarking is the systematic comparison of components of performance in an organisation, against best practices of the relevant organisations (Lau *et al.* 2005). The literature survey revealed that benchmarks have been introduced for service industry contracts (Barton, 2003); Fox (2006, 2006b). During interviews, the managers recommended that every contract should have a benchmarking clause, to evaluate whether services are delivered at a fair market price and at an appropriate level of service quality. Benchmarks lead to significant savings during the targeting of a large and diverse business market (Gomez-Arias and Montermoso, 2007).

Description	Benchmark
Percentage of supplied components: qualifies ISO 9000	86%
Percentage fraction practising quality control effectively	82%
Fraction of defective components supplied	1% - 5%
Percentage frequency of defective components supplied	1% - 5%
Percentage delay in supplying or receiving orders	1% - 5%
Average time delay in supplying or receiving deliveries	25-48 hours
Delay in supply due to outsourcee lacking capability	18%
Delay in supply due to error in order request	1% - 5%
Delay in supply due to incomplete delivery	0% - 5%
Delay in supply due to error in delivery destination	0% - 1%
Delay in supply due to error in delivery note	0% - 5%
Delay in supply due to error in invoice	0% - 5%

Table 7.1 List of Benchmarks

In order to focus on current research, the benchmarks are set for assessing the performance of outsourcing operations. The generic process of benchmarking comprises four main steps: plan, collect, analyse and adapt. As an outcome of the questionnaire survey and interviews, a number of benchmarks has been established, and are listed as Table 7.1. There are benchmarks set up for price, quality and delivery. The expressions 7.2 and 7.3 show the price benchmark and cost variation. Expression 7.4 and 7.5 benchmark the quality dimension. These benchmarks could be used especially when comparing outsourcing to in-house functions.

P_{bm} = Price standard/benchmark

P_{qf} = Quoted fair price

P_{rf} = Required fair price

C_v = Cost variation

C_a = Actual cost

C_e = Estimated cost

K_{qa} = Quality assurance

n_{rej} = Number of rejected parts

n_{rec} = Number of parts received

K_{dela} = Delivery assurance

$n_{on-time}$ =Number of on-time deliveries

$n_{t-delivery}$ = Number of total deliveries

$$P_{bm} = \frac{P_{qf} - P_{rf}}{P_{rf}} \times 100 \quad \ldots (7.2)$$

$$C_v = \frac{C_a - C_e}{C_e} \times 100 \quad \ldots (7.3)$$

$$K_{qa} = \frac{n_{rej}}{n_{rec}} \times 100 \quad \ldots (7.4)$$

$$K_{dela} = \frac{n_{on-time}}{n_{delivery}} \times 100 \quad \ldots (7.5)$$

7.4 MANUFACTURING LEVEL AGREEEMENT

The manufacturing level agreement describes explicitly, in precise and clear wording, the types, scope and nature of all the manufacturing requirements (quantity, batch size, lead time, quality, frequency of delivery, flexibility in delivery quantity). The manufacturing level agreement also includes guidelines enabling the outsourcer to measure the outsourcee's performance, by regularly monitoring the progress against agreed benchmarks. Tafti (2005) highlighted the risk factors associated due to outsourcing contract such as loss of privacy and security, decision process, outsourcing scope, diminished technical returns, hidden costs and loss of expertise. Initially, the guidelines of preparing an outsourcing agreement are listed based on information collected through literature survey. The guidelines are moulded for manufacturing sector after discussions / interviews with the managers. Finally, as a test case agreement procedure was presented to Totalli SRL and Newton Equipment. The feedbacks received are incorporated those adds uniqueness to this study.

The detail of how to write and implement a manufacturing level agreement is given as follows:

7.4.1 TRANSFER OF ASSETS

For an outsourcee to carry out the outsourcing of manufacturing, it may be necessary to transfer assets from outsourcer to outsourcee. Both participants need to make more commitment, mutual adoption and contribute learning and resources (Wang and Kess, 2006). The asset transfer is affected through the sale agreement between outsourcer and outsourcee. Independent valuation of the assets, as part of the manufacturing level agreement, may also be required. The assets transferred may include hardware, software licences and leases on equipment, patent licences and intellectual property rights. The transfer of assets may be subjected to tax and stamp duty that should also be addressed in the contract. Totalli has transferred product-design specifications to its outsourcee for manufacturing. Since SUPD is not solely dedicated to Totalli, and is manufacturing for a number of other companies, agreement was signed for manufacturing the particular

products (products manufactured according to the specifications supplied by Totalli) exclusively for Totalli.

7.4.2 TRANSFER OF STAFF

Transfer of staff from outsourcer to outsourcee is a common feature of an outsourcing arrangement. In the United Kingdom, Labour Regulations 1981 and section 33(1) of the Trade Union Reform and Employment Rights Act 1993, require elaborate procedures to be completed before a staff transfer can take place, and that the staff's existing terms of services be granted in their transfer (Lee, 1996). The outsourcee is responsible for paying for the transferred staff, and that cost is passed on to the outsourcer, as part of the manufacturing level agreement. In the case of Totalli (outsourcer) and SUPD, there has not been a transfer of staff.

7.4.3 COSTING AND PAYMENT

It is emphasised that the manufacturing level agreement includes costing, payments and penalties' terms. It should also state when, how and to whom payments should be made, and the amounts and the structure of the payments. Kulmala *at el.* (2006) pointed out outsourcing problems due to transactions and transaction costs differ between different governance structures in business relationships. It may be possible that some manufacturing services can be obtained at a lower cost in two years time, because of reductions in technology cost. Avoiding outsourcing contracts that may turn out expensive in the long-term, and difficult to terminate, is recommended. For example, in one of the analysed cases, the costing and payments agreement between Totalli and SUPD is very simple and straightforward. Totalli is solely responsible for freight charges (land, sea and air). The cost of the product is negotiated flexibly, taking into account all the internal and external factors, such as fuel cost, currency exchange rate and any other unexpected hidden charges. Totalli makes part of the payment at the beginning to facilitate SUPD in purchasing raw material and/or relevant resources. The remaining part of the payment is transferred before the shipment of the product (container or small parcel).

In exceptional circumstances when there is a need for new materials or technologies or capabilities those are patented and are costly, the decisions must be reached with mutual willingness of all participants and must be added in the MLA (contract). The MLA should include detail of all the itemised costs involved such as total cost, allocation of cost, payment terms and in case of contract termination and in case of dispute how the settlements of the remaing assets or debts should be done. The managing director of Newton Equipment explained with an example that certain materials or components are not available in small quantities; the manufacturer has to buy them in large quantity. In case of unforeseen circumstances, the outsourcing participation breaks down. The manufacturer is left with certain materials those were purchased for the company. It is not feasible to ship the un-processed material from China to Europe and it may not be possible to recover cost by selling the remaing materials. After discussion with managers, the author proposed that it may not be possible to include all possible details. There will always be some hidden issues left. These issues should be resolved with mutual agreement. If the issues could not be resolved with mutual agreement, then independent mediator should be involved. And if the mediation fails, which court will have jurisdiction to hear the case (Solicitor's Feedback).

7.4.4 WARRANTY AND LIABILITY

The inability of the outsourcee to comply with the manufacturing level agreement (unable to manufacture required order in time) makes it liable to be sued for damages by the outsourcer. From both the outsourcer and the outsourcee point of view, it is appropriate to include an express warranty in the manufacturing level agreement, to indemnify a participant for breaching the contract and compensating the other participant for losses incurred. It is important to ensure that losses are recoverable, by explicitly providing for them in the contract (Lee, 1996).

Totalli and SUPD have developed a very successful relationship. SUPD is responsible for replacing any defective component or product, but it is time-consuming to return the component or the product to SUPD and wait for replacement or repairs. However, Totalli has a highly-skilled workforce that repairs most of the components, and only a small

fraction is left for replacement. This strategy saves time and money, and customers are assured that after sale, their product's warranty is secured (Totalli customer-survey report).

7.4.5 DISPUTE RESOLUTION AND AGREEMENT TERMINATION

In order to complete a transaction, there are a number of activities involved in the outsourcing of manufacturing operations between Totalli and SUPD. With the increase in outsourcing activities, there are possibilities that participants may not follow the contract agreement and this might result in a dispute. Instead of following an expensive legal system to resolve a dispute, a proper dispute-resolution mechanism is included in the agreement. The dispute could be resolved through an independent third party (arbitrator or consultant). In case the dispute cannot be resolved, and ends in agreement termination, the consequences of the termination should be taken into account and reasonable guidelines should be included in the outsourcing agreement. The outsourcing agreement covers issues, such as the buying back of assets (hardware, software and human resources), the price equation of the buy-back, and transfer of third party contracts and leases, with assurance from participants that the transfer is smooth and proper.

Currently, Totalli has been transferring only product-design specifications for manufacturing. The agreement between Totalli and SUPD explicitly includes clauses in relation to the termination of manufacturing, in case the manufacturing agreement requirements are not met, or if the outsourcee goes into liquidation or receivership.

7.4.6 OWNERSHIP OF INTELLECTUAL PROPERTY RIGHTS

As detailed above, written agreement protects both outsourcer and outsourcee, in case of changes in their circumstances, and safeguards the interests of all the participants. The outsourcing agreement between Totalli and SUPD explicitly includes ownership of intellectual property rights, such as copyrights and patents developed from outsourcing activities. In case of termination of the manufacturing agreement between Totalli and SUPD, dispute resolution of the intellectual property rights is also included.

7.4.7 INFORMATION SECURITY AND CONFIDENTIALITY

In outsourcing of manufacturing operations, information security includes product design, software programme codes and business data. When manufacturing activities are outsourced, the outsourcer (Totalli) cannot fully control the information security of its manufacturing functions/activities. Hoecht and Trott (2006) investigated outsourcing risks due to information leakage as it depends upon core competencies and nature of industry and main source of risk could be service provider staff and consultants. The risk could be due to lack of social control that results in loss of reputation, professional ethics and trust. Companies having unique competencies need to be protected against imitation by competitors.

After analysing information acquired through literature survey and feedbacks from Newton Equipment and Sonic Enterprise, the author suggested that Totalli and SUPD should include levels of information security and confidentiality required by both participants in the manufacturing level agreement. Totalli may rely on a manufacturing level warranty to claim from the SUPD for loss due to non-compliance of standards; instead, it is preferred to implement preventive measures and include them in the contract. Since SUPD has access to Totalli's commercially sensitive data. The SUPD is urged to not to reveal Totalli's designs to anyone else, both during the agreement period and after termination or end of the agreement period. In order to make sure confidentiality is maintained, an external agency could be hired to protect the interst of the company but it adds to additional cost.

7.4.8 ECONOMIC BENEFITS

The outsourcing relationship focuses preliminarily on cost minimisation and operational efficiency. Outsourcing urges joint focus on the business and mutual goals of both outsourcer and outsourcee. Totalli chose SUPD as its outsourcee, using a supplier selection model. Totalli would have outsourced to SUPD only if the acquisition cost was equal to, or less than, the in-house manufacturing cost. Outsourcing is sustainable if SUPD earns sufficient profit, supplying at a price that is less than, Totalli's in-house manufacturing cost

without compromising quality and delivery. Therefore, both outsourcer (Totalli) and outsourcee (SUPD) gain economic benefits by engaging in an outsourcing agreement.

7.4.9 PRIMARY TRANSACTION

In outsourcing, the primary transaction is related to infrastructure. The outsourcing relationship matures as outsourcer and outsourcee invest jointly in infrastructure. In the case of Totalli and SUPD, the equation of the primary transaction is different. Totalli invests in the product identification, product development and redesign, whereas SUPD invests in its technological and manufacturing capabilities. Both outsourcer and outsourcee save in the primary transaction by engaging in outsourcing because they benefit from each other's resources.

7.4.10 CONTRACTUAL COMPLETENESS

The outsourcing contract covers transfer of assets, staffing, pricing and payments, warranty and liability, a dispute-resolution mechanism, termination, intellectual property matters and information security (Lee, 1996). As the outsourcing relationship matures, cooperation becomes more prominent. Totalli transfers product specifications and requirements to SUPD for manufacturing. In case SUPD does not abide the confidentiality rules, the penalities should also be included in the agreement.

7.4.11 OUTSOURCEE BEHAVIOUR CONTROL

The outsourcee behaviour-control mechanism changes from a structured focus on operational efficiency, to a more structured concern for the relationship's impact on strategic direction. Rebernik and Bradac (2006) pointed out the most significant obstacles preventing an efficient outsourcing arrangement are misunderstanding between participants regarding their objectives, policies and culture. The outsourcer and outsourcee may have communication and monitoring problems and both sides are controlling.

In order to avoid any confusion, Totalli and SUPD have clearly explained their demands to each other before entering the arrangement. Totalli and SUPD are successfully integrating, despite their cultural differences. Totalli is planning to assess SUPD behaviour control by preparing quarterly reports. It is important that the outsourcee only fulfils the demand of the outsoucer and avoid establishing its own business units as a competitor

7.4.12 LABOUR DEMARCATION

The demarcation of labour between the outsourcer and the outsourcee is specialised in the case of outsourcing of small and medium sized manufacturing companies, following the scope of the contract. Totalli and SUPD are working together for continuous innovation, but with different capabilities and specialisations, by complementing each other. Totalli has a very small but highly-skilled workforce that is capable of maintaining and improving quality, and complying with European standards. A monthly report is prepared, discussing labour demarcation.

7.4.13 CORE-COMPETENCE MANAGEMENT

Outsourcing places responsibilities for manufacturing functions in the hands of the persons most capable of performing these activities successfully. The transfer of personnel from outsourcer to outsourcee is recognised as valuable, rare and appropriate, as these personnel become a strategic resource. Totalli specialises in motorcycles and mopeds. Due to the nature and size of Totalli, no human resources were transferred to SUPD, and the outsourcer is running its business successfully. Core-competence management is assessed by the number of new products introduced every year, and by the enhancement of its reputation in the local market.

7.4.14 RESOURCE EXPLOITATION OF OUTSOURCEE

The outsourcee (SUPD) offers resources (technological, hardware, material) initiatives to the outsourcer (Totalli). The outsourcee also presents a set of complementary capabilities, skills, competences and methods. Totalli selects products from the outsourcee which can

be easily modified to meet the demand of the local market, instead of designing products from the drawing stage. The design alterations are introduced with mutual understandings. By adopting design alteration approach, Totalli SRL saves times and resources. On the other hand the SUPD acquires knowledge about the design requirements in other markets. Resource exploitation is evaluated by estimating the cost of the investment required for developing the same resources in-house, less cost paid to use outsourcee resources. Taking into account the cost of energy in Europe, utilising resources owned by SUPD is to the limit, until additional cost is demanded.

7.4.15 ALLIANCE EXPLOITATION

The outsourcing relationships are collaborative; the outsourcer and outsourcee get involved in making sure that requirements are fulfilled. It is also ensured that any tangible or intangible resource is available for use. The company (Totalli SRL) and SUPD based in China has joined in an outsourcing relationship, because both complement each other in their expansions. There is a time difference of six hours. The senior manager said that the difference in time causes problems, especially when he wanted to give instructions via telephone or webcam. There is a maximum of three to four hours of window time, when a UK-based company and China-based supplier are open during their regular business hours.

7.4.16 OUTSOURCING RELATIONSHIP EXPLOITATION

Outsourcing is initiated by sharing of the information between outsourcer and outsourcee, and may be followed by joint planning. "*In the beginning, the services of a consultant were used for understanding each other because did not want to get lost in translation*" (Manager Totalli SRL). Now, the Totalli SRL and SUPD are sharing information on regular basis in order to simplify and smooth running of processes and activities between them.

The managing director of Newton Equipment emphasized the importance of education and training for relationship development and quoted as saying:

"In spite of all the problems (limited funds, unable to relieve staff and unavailability of the right training provider), the company is arranging staff training programmes according to its convenience. It is also believed that education and training programmes promote continuous improvement and encourages relationship-development with suppliers (outsourcees)."

7.4.17 SOCIAL EXCHANGE EXPLOITATION

The scarcity of investment for resources creates social exchange and engages Totalli and SUPD in acquiring valuable input. As the outsourcing process matures, inter-personnel exchange from purely economic, to non-economic, is encouraged.

7.5 PRE-CONTRACT SETTLEMENTS

Negotiating an outsourcing agreement could be a lengthy and resource-consuming process. Once the manufacturing agreement is implemented, it is difficult to amend, and takes up a substantial amount of extra resources and time. By carrying out literature survey, a number of problems have been identified due to contracts. By analysing the information collected through literature survey and discussions with experts, the author proposes resolving all possible issues before signing the agreement such as; updating of outdated outsourcing contracts, improving service quality throughout the contract, acquisition of technical knowledge of the relevant field and introduce flexibility to accommodate necessary changes. The final agreement should be free of errors and have the capacity to introduce any modifications.

Totalli and SUPD have simplified the negotiation procedure by including a checklist of tasks, and introducing the technicalities in the draft agreement in the initial stage. The checklist produced a skeleton agreement that was finally developed into a well-structured agreement.

7.6 IMPLEMENTION OF OUTSOURCING CONTRACT

The outsourcing contract is the number one key issue in a successful outsourcing relationship (Lacity and Hirschheim, 1993). A watertight contract is the only mechanism to ensure that the expectations of the outsourcing customers are met (Lee, 1996). A comprehensive outsourcing contract lists all pre-contractual negotiation and post-contractual management. Three types of contracts are highlighted by Lee (1996): complete outsourcing contracts, facility-management outsourcing contracts and system-integration outsourcing contracts. Complete outsourcing of manufacturing involves the transfer of all manufacturing functions/activities of an organisation, along with its existing assets such as hardware, software and personnel, from the outsourcer to the outsourcee.

In this study, a contract for part-outsourcing of manufacturing functions/activities is formulated. Such contracts are lengthy and complicated, involving the entire range of assets and relevant legal issues, and are short to long-term. The outsourcee (SUPD) assumed a part of the risk and manufacturing responsibilities of providing the outsourcer with its manufacturing requirements.

7.7 POST-CONTRACT MANAGEMENT

The agreement is the only definitive, legal document defining the relationship between Totalli and SUPD. According to the managing director of Newton Equipment, an explicit, detailed and well-written agreement is the key to a successful relationship, because of ease of management due to the necessary mechanisms having been built into the agreement. Totalli has assigned the outsourcing agreement management to a very experienced manager, who understands the services provided by outsourcee (SUPD), or any other outsourcee. There is direct communication between top management and managers dealing with post-contract management, so that any problems can be notified to top management as soon as possible.

7.8 DISCUSSIONS

The language of communication between the supplier and the company is English. The supplier's staff can communicate very well in English. In spite of this, managing director of Newton Equipment advised including the language for communication in MLA. It was told that the company has been encountering problems due to language differences.

"The supplier (manufacturer) was asked to provide an estimated quote for manufacturing a golden doorknob handle. The supplier quoted a price that was very high. Upon inquiry, it was found that the supplier quoted a price in order to manufacture the doorknob handles from gold metal."

The managing director of the company stated:

"The problems were caused due to differences in language between the company and the supplier. It is expected that the problems occurring due to differences will be reduced with the experience curve. The manager acknowledged a heavy usage of jargon and 'short words' in verbal communication, and even in written communication. The Chinese counterparts may have learnt the English language according to the Oxford or Cambridge dictionary rules. It is possible that they may not be familiar with the jargon and 'short words' used by the company. The staff of the company would have been using jargon and 'short words' in communicating with the Chinese supplier that may not have helped the supplier to understand the requirements of the company. The author advised the company to formulate guidelines when communicating with foreign suppliers, especially those whose native language is other than English. The company was instructed not to use jargon or 'short words', but in case the jargon or 'short words' are unavoidable, it is essential to explain them."

The expectations of the company and that of the supplier may change with time, as outsourcing progresses towards maturity (tactical outsourcing changes to strategic and then to transformational outsourcing). The participants analyse the outsourcing and try to change their contributions. Any change on their part requires incorporating change into the MLA. Even an improvement in any activity that is connected with outsourcing, is

considered a change, and must be updated in the agreement. The author recommended that the company include all possible details in the contract. The managing director of the company agreed and provided the following feedback:

"It may not be possible to draw up an MLA that includes all the activities of the company and that of the supplier. There is always something missing from the MLA. It is also difficult to define all the requirements of the company. The process is started with simple requirements and is improved with the experience curve. At the beginning of the process, the MLA is signed and the benchmarks are set. In spite of all the changes in the manufacturing operations, the changes in the MLA are made in order to save resources."

The author pointed out that in order to avoid future problems, the MLA must include the requirements (demands) of the company and the expectations (contributions) from the supplier. It is also essential that the MLA includes rewards and penalties if so desired; in case the company or the supplier could not follow the MLA. The managing director acknowledged the suggestion and made the following comments:

"Most of the time the supplier (outsourcee) understood what the company (outsourcer) required. Due to financial restrictions imposed by agreement constraints, sometimes the outsourcee could not provide what the outsourcer requires. The company provides help to the outsourcee in its expertise areas (areas of several years of experience), in order to transfer knowledge. The company is using a reward system in order to motivate suppliers. The company is not in favour of introducing a penalty system. The penalty charged to the supplier is indirectly paid by the company, or the supplier may try a trade-off in order to meet the requirements of the company. The system may not be aligned with the objectives of the supplier."

The author considers that the MLA should be flexible enough to accommodate any changes in the outsourcing process. The MLA should include specific objectives and expectations of both outsourcer and outsourcee, and flexibility for participants to change for improvement. The author identified that most of the time the company tried its best to include complete detail of all of the outsourcing activities in the MLA. In spite of all the

effort, there is always some detail that is not included in the contract. For example, the companies forget to include the renewal procedure of the contract.

The managing director acknowledged the inclusion of the agreement renewal clause and added his comments, which are as follows:

"The company will be considering including a clause of renewing procedure in new MLAs. It is a possibility that the company does not want to renew the contract with the existing supplier, and would rather change the supplier. It would be convenient to select a new supplier and sign an updated contract."

As an outcome of this study, the author identified that the outsourcing policy of a company is not usually changed; however, there are circumstances when the policy requires modifications. Outsourcing policies depend on factors related to the objectives of the company, and outsourcing. A company changes its policy, only when its objectives are not met, or, by changing the policy, it becomes feasible to improve the outsourcing process.

The managing director commented:

"It is the company's policy to keep all activities simple and straightforward. The policy is changed in order to adapt to outsourcing development. Still, there is a long way to go before the policy of the company improves to a stage, where it could practise outsourcing to transformational or at least strategic level."

The objectives of the company are to meet the requirements of the market/customer (for whom the company acts as supplier). With the adoption of outsourcing, there is no change in the ultimate objectives of the company. The activities of the company are changed, which include satisfying customer's requirements, maintaining its own image, enhancing profit and linking with suppliers.

The managing director provided feedback to the author as follows:

"Objectives are set at the beginning of the outsourcing. After a while, working with the supplier, you find that the objectives are misunderstood, because they are not explained clearly. The objectives did not include what the supplier could achieve, and how it should contribute to outsourcing. The company's objectives must be made as clear and simple to understand as possible, in order to ensure better understanding by the supplier. It should also be explained how the supplier would coordinate in meeting the demands of the market."

According to the literature review, the successful management of outsourcing operations depends upon both outsourcer's and outsourcee's expectations. The author believes that how the outsourcing activities should be managed, and who should control the outsourcing process, must be clearly included in the MLA. In this regard, the managing director narrated his experience.

"The supplier tried to manage the outsourcing in a way that suited his objectives. The supplier wanted to manage outsourcing in 'x' way, whereas the company wanted to manage the same in 'y' way. The problem did not stop there; there was even tension as to who was in control. In simple words, there was a conflict as to who should take control of the outsourcing management."

The senior manager of 'Four Rivers Consultants' highlighted one of the causes of problems in outsourcing management:

"In order to preserve secrecy, organisations exchange only very essential information that may not be enough for the supplier to understand the objectives of the company."

The author discovered that in the beginning it is difficult for companies to manage outsourcing effectively, and they subsequently give up the management of the outsourced activity. Without realising it, the company interferes and restrains the supplier's outsourcing activities. The senior manager of Newton Equipment was quoted as saying:

"The manufacturing activities were performed in-house for many years; therefore, the operational managers have been trying to control the same activities naturally."

The author discussed the behaviour of companies towards the cost of outsourcing. The manager of 'Four Rivers Consultants' expressed that:

"Most of the companies wanting to outsource their manufacturing operations were interested in reducing costs. The companies wanted to find suppliers who could reduce their cost without knowing any other detail."

By carrying out this study, the author identified a number of unaccounted costs which should be taken into account for outsourcing decisions. These costs are: 'Vendor (supplier) Search Cost', 'Contracting Cost', 'Contract Management Cost', 'Currency Fluctuation', 'Customs and Excise Costs', 'Staff Retaining Cost', 'New Software/Hardware Systems Acquisition Cost', 'Transition Cost' and 'Post-outsourcing Cost'. In spite of accounting for all these costs, there are some new, hidden outsourcing costs, which have not yet been discovered.

The author proposed that the suppliers should be provided with essential information and expected to provide both dedication and lower costs. The company (outsourcer) should be responsible for setting up manufacturing goals, whereas the supplier (outsourcee) should be responsible for organising manufacturing activities.

The managing director was asked whether the selected supplier had been practising the quality-control programme effectively.
The managing director explained:

"The managing director showed a component that was discoloured. The company was liable for repairing/replacing and fitting of the component. The manufacturing of the component was outsourced to an external company, which specialised in material processing. The manufactured component satisfied all the criteria of dimensions, weight, and appearance. The component was designed for the luxury market and was supposed to maintain its elegant appearance which is dependent on its colour. However, the outer part of the component that was directly exposed to the changing weather was discoloured. This

needed investigating to propose a solution; otherwise it would end up in loss of reputation. The problem can be resolved through various considerations."

The author found that the defective parts can be replaced and the supplier will be liable for the replacement cost (labour cost). By replacing the component, the problem will not be solved, because the new, replaced part will also discolour with time. It was necessary to find the real cause responsible for defective components.

The managing director expressed that:

"The decision to outsource was based on past experience that the manufacturing responsibility of the components would be passed over to the supplier. It was not planned to test the material as to how the appearance will change when exposed to the atmosphere over a period of time. The company informed the supplier to rectify the problem of discolouration. The supplier informed the company that the material of the components was mixed with some recycled material that could be responsible for undesired properties."

The company introduced itself as a tier-1 auto-parts manufacturer. The supplier assumed that the company will be buying components in multiples of 10,000 and quoted a price accordingly. The supplier was informed that the company could consume only 20% of the presumed quantity. The supplier refused to go ahead with the agreement. Upon further inquiry, the supplier said that it was not profitable. The supplier was even offered a higher price, but still refused to proceed.

The managing director highlighted that:

"During the outsourcee selection process, neither the selection criteria are fully defined, nor are the suppliers fully investigated with respect to their facilities and work. Before selecting a supplier, it must be visited by the company's decision-maker or by a third party agent. During the supplier search, the suppliers were assessed by analysing websites. The deal seemed promising and the drawings were sent for components manufacturing. The manufactured components were of correct design and dimensions, but the material used

was of poor quality. It was believed that the suppliers were good, but it resulted in losing money. Later, the suppliers were visited in China, and it was found that the reality was different from that which was available on websites. The supplier said that when the company placed the real order, the correct grade material will be used. The company placed an order for 500 components, whereas the supplier expected an order size of 10,000 components minimum."

Qureshi *et al.* (2007) referred Schultz (2005) suggested seven guidelines for keeping a healthy relationship, which include 'sharing the benefits, realistic request for proposal (RFP), going for hype-vs-reality check, measuring everything, keeping accurate records, it is not an all-or-nothing game and nobody is perfect'.

The managing director emphasised that:

"*We are living in very fast-developing era. It is advisable to exploit external sources, instead of relying on limited in-house resources. The company also considers it important to involve customers in development planning by acquiring their feedback. It is part of our business strategy of maintaining a very close relationship with our customers and suppliers. It is always good to have contact with all suppliers. With one of the suppliers, the company accidentally found out about the problem that they were having. The supplier was not able to deliver a safe product due to a technical fault. The company stopped the product but did not cut off the links. Later, the supplier resolved the problem and company was briefed as to how the defect was fixed. If the company had not maintained the link, it would have been impossible to gain the experience of defect-fixing.*"

The author enquired and found that the company has been outsourcing components manufactured by castings, die-casting and moulding, or by some other special process. It is not feasible for the company to invest in moulding and casting machinery. The tooling is provided, or the outsourcee is paid to make the tooling for the job. In this modern age, it is not possible to have every facility to manufacture all kinds of components. For instance, a car manufacturer does not produce electronic equipment for houses; instead, their manufacturing is transferred to some specialised firms. Similarly, every automotive

manufacturer outsources five tyres per automotive product, to a specialist tyre-manufacturer.

The managing director elaborated that:

"*Outsourcing management is entirely a matter of experience and a systematic approach. For example, in order to acquire tyres, the demand is outsourced to a competitive tyre-manufacturer rather than a small, backstreet manufacturer. The company outsources its forging processes to a particular manufacturer, because it is suitable to meet the company's demand. The company identified a number of supplier companies, which were efficient with the forging process, but they were not interested in doing forging in the numbers Newton Equipment wanted. The company had been forging low numbers – high-value, by contrast with high numbers – low-value requirements. When searching for a supplier for a component, it is advisable to look at the related industry. In order to find a specific supplier, a variety of companies should be searched for in that industry, and then decisions should be made based on agreed criteria. Simply put, an organisation only outsources when it does not have adequate in-house capability/capacity to cope with the demand. The company also does not make nuts, so the company outsources to other organisations which are specialists in nut-manufacturing. The company also owns an anodising facility that is capable of high-quality surface finish, but it does not enable the organisation to be competitive from a price perspective. It is costly to run the anodising company, but for the sake of ownership, the profit benefits can be sacrificed.*"

7.9 CONCLUSIONS

The procedure to draw and implement a manufacturing level agreement (contract) has been explained in detail. The important factors need to be considered for drawing an outsourcing contract such as transfer of assets, transfer of staff, costing and payment, warranty and liability, dispute resolution and agreement termination, ownership of intellectual property rights, information security and confidentiality, economic benefits, outsourcee behaviour control, labour demarcation, core-competence management, resource exploitation of outsourcee, alliance exploitation, outsourcee relationship exploitation and social exchange exploitation are highlighted. Furthermore, all stages of the outsourcing are included,

beginning from the first transaction to the end of the specified contract period, and even in the event of early termination of the contract, due to unforeseen circumstances. Finally, manufacturing level agreement implementation procedure is also explained.

In order to illustrate the manufacturing level agreement, the real life outsourcing experience of Totalli SRL and SUPD have been included in this chapter.

Totalli invests in the product identification, product development and redesign, whereas SUPD invests in its technological and manufacturing capabilities. Both outsourcer and outsourcee save in the primary transaction by engaging in outsourcing because they benefit from each other's resources.

It was found out that Tottali has not transferred or layed off any of its staff. Totalli SRL has invested time and resources for the training of its staff. The manager explained that staff is highly trained for multi-skill jobs and can coupe with changes due to outsourcing.The designs (specifications) of the products were the only asset that were transferred to the outsourcee. It was identified, when Totalli SRL requests an order only a part of the money is transferred to cover the cost of raw materials. The rest of the outstanding balance is transferred when the order is ready for shipping.

The agreement also covers the buying back of assets (hardware, software and human resources), the price equation of the buy-back, and transfer of third party contracts and leases, with assurance from participants that the transfer is smooth and proper.

It was also found out that outsoucing is sustainable, if both outsourcer (Totalli) and outsourcee (SUPD) gains economic benefits by engaging in an agreement. Totalli and SUPD have simplified the negotiation procedure by including a checklist of tasks, and introducing the technicalities in the draft agreement at the initial stage. The checklist has facilitated to produce a skeleton agreement that was finally developed into a well-structured agreement.

According to feedback from an experienced solicitor, the agreement should include which court will have jurisdiction to hear the case, if the mediation fails.

Chapter 8

CONCLUSIONS

8.1 INTRODUCTION

This thesis started by analysing existing outsourcing models and frameworks, and investigating their operational applications that lead to the identification of their weaknesses. The majority of them have addressed only a part of the outsourcing operations. Furthermore, the majority of the existing outsourcing models and frameworks are formulated for IT and the service industry. This justified the need for conducting this research in the field of outsourcing of small and medium sized manufacturing companies. Thus, the research was focused on formulating a number of outsourcing decision models for small to medium sized manufacturing companies. The information from manufacturing companies was gathered about outsourcing operations, using questionnaires and interviews.

By carrying out this research, outsourcer's criteria for outsourcee selection for small and medium sized manufacturing companies are identified. Then, a model is formulated for numerical evaluation of outsourcer's criteria for outsourcee selection and a second model for outsourcee selection is formulated. Finally, a model for drawing up and implementing a manufacturing level agreement is formulated.

8.2 ACHIEVEMENT OF AIMS

The main aim of developing outsourcing models was to equip decision-makers with a suitable tool for decision-making. The models could provide guidance on how these decisions should be implemented in a manufacturing environment.

The thesis achieved the following aims:

1. *Identification of outsourcer's criteria for outsourcee selection in small to medium sized manufacturing companies*

The identification of outsourcers' criteria for outsourcee selection was carried out systematically in stages; literature survey, questionnaire survey and discussions / interviews with managers of Newton Equipments and Sonic Enterprise. The criteria were sorted into groups according to their similarities and differences. For the current research, both qualitative and quantitative criteria were selected. With the assistance of managers a set of eight criteria and twenty-six sub-criteria were identified, after analysing the information obtained from the literature survey and questionnaire survey.

The identified criteria and sub-criteria address all aspects of cost, delivery, quality, reputation, finance, technology, management and environmental. They are different from the criteria and sub-criteria used in previously publised supplier selection models and frameworks in the areas of IT, services, product design, engineering and manufacturing, however, contain their essence.

All outsourcee selection criteria and sub-criteria are defined to meet the requirements of small and medium size manufacturing outsourcing companies, approved by the managers of manufacturing companies. Furthermore, the procedure followed in this research for the identification of criteria is systematic and well structured.

2. *Numerical evaluation of outsourcer's criteria*

The analytical hierarchy process (AHP) and cluster analysis (CA) have been used successfully for organising subjective opinions into objective judgements (transformed into matrices and surveyed Eigenvectors). The result is an eigenvector that is representative of the entire range of companies surveyed. Thus, AHP–CA model is formed for numerical evaluation of outsourcer's criteria for outsourcee selection.

The model demonstrates matrix construction and calculation of the normalised eigenvectors. The pair-wise data collected using second questionaire are arranged in a matrix and a normalised eigenvector of this matrix is calculated. The evaluation of priority weights of outsourcee selection criteria and sub-criteria using normalisation is simpler (less complicated) than the eigenvalue method.

The AHP-CA model is used for numerical evaluation of the outsourcer's criteria for outsourcee selection. It was discovered that for outsourcing in the manufacturing of small to medium size companies, experts have allotted the highest importance to quality, and the least to organisational and environmental laws, for evaluating outsourcing participants. The trigonometric function cosine and the Eucleadian norm are applied for clustering. Both techniques give comparable results although one technique (the Eucleadian norm) is quicker and requires fewer calculations than the other technique (cosine). The analytical hierarchy process and cluster analysis are proved suitable methods for integrating qualitative and quantitative criteria in the manufacturing sector. It was also discovered that an AHP-CA model makes the outsourcing participant-selection process transparent.

3. Formulation and application of model for outsourcee (supplier) selection

The model for outsourcee selection was formulated using AHP-CA and criteria scoring. The model has been applied successfully for matching a particular outsourcer with the best potential outsourcee. A real manufacturing company, Totalli SRL was selected in order to compare the results obtained by empirical methods by this company and the results generated by the proposed model. Totalli SRL initially drafted a list of Chinese companies as potential partners for outsourcing. Basically, the procedure starts by attributing ranking scores to each selection criterion, according to the ability of each candidate outsourcee. The outsourcee having the highest total score is selected as the most suitable outsourcee. The results have satisfied the management of the company and earned their approval. The management recommended introducing some modifications according to types of products manufactured, locations of candidate outsourcees and relationships between outsourcee and the outsourcer.

4. *Formulation of guidelines for drawing up a manufacturing level agreement*

Guidelines are proposed for developing a manufacturing level agreement (MLA). The MLA also included procedures for its implementation, in order to run problem-free outsourcing. Benchmarks are also introduced to monitor the progress of the outsourcing process. The guidelines can be used for structuring the MLA for initiating outsourcing with a number of companies. This may lead to the possibility of further research into multi-sourcing. Furthermore, all stages of the outsourcing are included, beginning from the first transaction to the end of the specified contract period, and even in the event of early termination of the contract, due to unforeseen circumstances. Finally, manufacturing level agreement implementation procedure is also explained.

8.3 OVERVIEW OF ACHIEVEMENTS

This research study began with the identification and evaluation of market outsourcers' criteria for small and medium sized manufacturing companies. It started with a review of criteria used in previously published supplier selection models in the sectors of IT, services, product design, engineering and manufacturing. In order to make sure that the most suitable criteria were selected, it was considered essential to prepare a questionnaire for collecting information from small and medium sized manufacturing companies. To enable a more precise selection of criteria it was then decided to set up a number of interviews with the managers of a few representative companies who were available and willing to help with the research. These criteria were then sorted or grouped in such a way that each group represented a similar/same category.

Eventually, with the help of these managers, a set of eight outsourcee selection criteria with twenty-six sub-criteria was finalised. The identification of the criteria and sub-criteria was carried out based on information acquired from real companies and address all the aspects of cost, delivery, quality, reputation, finance, technology, management and environment.

The information collected through the questionnaires was compared with that obtained from the literature survey. They are different in context from the criteria and sub-criteria

used in previously published supplier selection models and frameworks in the areas of IT, services, product design, engineering and manufacturing, however, contain their essence. According to the literature survey, there was not enough detail regarding choosing procedure of supplier selection criteria and sub-criteria.

The procedure followed by this research in the identification of criteria is systematic and well structured. A number of novel developments are made by carrying out this research, an overview of which is as follows:

The analytical hierarchy process, developed by Saaty (Saaty, 1990) applicable for ranking, assigning priorities and decision making based on single respondent has been considered. However, this method on its own cannot be used for group decision analysis. The AHP method can be enhanced to include group decision analysis when combined with cluster analysis was proposed by Mei-yuan *et al*. (2006). These authors have applied the AHP-CA model for the outsourcing operations in software industry where the cluster analysis is carried out by using trigonometric cosine function that was derived from the dot product of two vectors. The priority weight vectors having cosine values close to one were grouped into one cluster. The result is an eigenvector that is representative of the entire range of companies surveyed. The elements of the priority weight vector represent the relative priority weights of criteria.

In this research the AHP-CA model is further developed by introducing the Euclidean norm for efficient grouping of the priority weight vectors into clusters. The priority weight vectors having the smallest Euclidean norm (distance) are grouped into clusters. The Euclidean norm (distance) defines the difference between priority weights vectors of two experts. It requires less calculations compared to cosine trigonometric function (phase angle difference). The calculations of the Euclidean norm (distance) are relatively simpler and quicker.

The cluster analysis is carried out using trigonometric function cosine and the Euclidean norm. The application of both techniques for clustering gives comparable results although one technique (the Euclidean norm) is quicker and requires fewer calculations than the other technique (cosine). By carrying out this study, it has been discovered that for

outsourcing in the small and medium sized manufacturing companies, decision-makers allot the highest importance to quality and the least to organisational and environmental laws. The AHP-CA is proved a suitable model for integrating qualitative and quantitative criteria for group decision analysis in the manufacturing sector.

The next stage in the research was the matching of a particular outsourcer with the best potential outsourcee. A real manufacturing company, Totalli SRL was selected in order to compare the results obtained by empirical methods by this company and the results generated by the proposed model. Totalli SRL initially drafted a list of Chinese companies as potential partners for outsourcing. Basically, the procedure starts by attributing ranking scores to each selection criterion, according to the ability of each candidate outsourcee.

The relative priority weight vector of the market surveyed criteria those are calculated using AHP-CA reflects the market in which the company would be operating. The relative priority weights of criteria shows the overall picture of what is needed to be achieved as reported by the respondents (experts). However, when selecting the outsourcee for a specific company, the particular criteria ranking of the company have to be considered. Therefore, in the selection process of the most appropriate outsourcee, three elements has to be considered; the previously defined 'vector of important criteria resulted from the information analysis of literature survey, questionnaire and interviews', 'the specific criteria ranking (scoring) identified by a particular outsourcer company' and 'the fulfilment of both general criteria (business / market) and specific criteria (outsourcer company) by the potential outsourcees'. In order to satisfy 'relative priority weight vector of important criteria' and 'the specific criteria ranking (scoring) of the companies', the 'snapshot vector components (relative priority weights of criteria)' has to be tuned with the 'specific company criteria (specific criteria ranking scoring)'. For example, the survey results may indicate that for the market/business quality has the highest ranking. But the specific company may rank the quality lower than price. In this case, the assessment of the potential outsourcee has to be made using a combination of the quality ranking in the general market, together with the specific ranking of the particular company which is outsourcing.

The priorities (importance weights) of each criterion and sub-criterion are then multiplied by corresponding criteria scoring and the results are summed to a final score. The outsourcee that achieves the highest total score in the model may be considered the most suitable. The validation of the model consisted of the comparison of the results obtained by using the AHP-CA and criteria scoring model to the results obtained by the empirical method. The AHP-CA and criteria scoring model led to the same results as empirical method, this indicates that the proposed model is right and effective. Furthermore, the model also ranks candidate outsourcees in addition to selecting the most suitable supplier. In conclusion it was proven that the developed method is consistent, faster and objective.

After a potential match between outsourcer and outsourcee had been identified, there was a need to draw up and implement a manufacturing level agreement (contract). In carrying out this research study, the important factors, which are required for developing a comprehensive contract, are highlighted. All stages of the outsourcing are included, beginning from the first transaction to the end of the specified contract period, and even in the event of early termination of the contract, due to unforeseen circumstances.

It was noted that the MLA process was not clearly explained to each of the outsourcing participants, as to what their responsibilities were. There was also not sufficient discussion, in order to establish suitable communication. It is possible for an outsourcing participant not to realise that what is clear to one, may not be clear to the other outsourcing participant. It is also identified that by setting up a two-way discussion, a better understanding of each other's requirements could be achieved.

8.4 CONTRIBUTION TO KNOWLEDGE

Most of the outsourcing research was conducted on IT and the service industry. The investigation of the data collected through the literature survey, highlighted that only a limited amount of research was carried out on outsourcing of small and medium sized manufacturing companies. The previous research was focused on outsourcing planning and success, ignoring the operational problems of outsourcing. Therefore, the current research was focused on the outsourcing of manufacturing activities within small and medium size

manufacturing companies. In order to evaluate the outsourcing performance, benchmarks were set as references.

A novel supplier (outsourcee) ranking method, involving the analytical hierarchy process, cluster analysis and criteria scoring was developed, and used for the selection of suitable outsourcees. The method was tested as a practical tool for an accurate assessment of candidate suppliers, in order to select the right outsourcee. The accuracy of the model results is limited only by the values of the criteria scores assigned by the decision-makers. The results obtained are presented, analysed and compared. These results are in close agreement with the actual decision made by the company.

The outcomes and conclusions from the research may have importance for researchers and practitioners in the field of outsourcing. The achievements of the research aims may be considered as a contribution to the body of knowledge.

The analysis of feedback received from the company revealed the following:

The outcomes of the outsourcing operations should be set by both outsourcer and outsourcee. In case of any changes in the requirements of outsourcer and/or outsourcee, the aims of the outsourcing must be redefined after mutual agreement.The outsourcing operational models of outsourcer and outsourcee must be aligned in order to fulfil their requirements. At contractual level, the reward system (bonuses or penalties) was not included by the company. The reward system motivated the outsourcee to manufacture products in order to achieve the desired performance. At feedback level, not only the outsourcer should evaluate the performance of the outsourcing operations and provide feedback to the outsourcee. It is also important that the outsourcee provides feedback to the outsourcer.The feedback should include complete details of where improvement is needed. The outsourcer and outsourcee should work together to mature their relationship.

8.5 STRENGTHS OF THE RESEARCH METHODOLOGY

The empirical survey (questionnaires and interviews) identified problems in the outsourcing of manufacturing activities. The research outcomes (empirical investigations)

are relevant to the real small and medium sized manufacturing companies which are outsourcing. Comparison of the data collected from the literature survey, and the data collected from real companies, supports the suitability of the research methodology. The research methodology brings academics and the experts from real manufacturing companies closer.

This thesis introduces a novel application of the research methodology on the outsourcing of small and medium manufacturing companies. The research has produced valuable information which provides the basis for further investigation and the formulation of new, outsourcing decision models. More hidden problems, such as 'minimum order size' and 'type of material used for small order sizes', 'lack of resources for staff training' were found, in addition to those already identified in the previous research and literature survey.

8.6 WEAKNESSES OF THE RESEARCH METHODOLOGY

Most of the information data collected through questionnaires and interviews was only from outsourcer companies. It was not possible to validate all the models based on a single company. Due to the nature of the research, each model was validated on a different company and in certain cases, only some parts of the models were validated.

The outsourcing defects information was collected from the literature survey, questionnaires and interviews. During validation of models, more outsourcing defects were identified, and it was difficult to modify and revalidate the model.

It was not possible to monitor the manufacturing activities of off-shore outsourcees. Due to trade secrets, only limited information was available. The same degree of difficulty was experienced during the application of outsourcing decision models for getting feedback.

The data could have been influenced by the biased behaviour of the outsourcing managers. The model validation process is also subjected to the bias of the managers.

Chapter 9

RECOMMENDATIONS FOR FURTHER WORK

This research study was carried out with the objective of enabling academics, outsourcing managers and practitioners to better understand the outsourcing of manufacturing activities. A better knowledge of the outsourcing activities may serve as a basis for the academics to carry out further research, and facilitate outsourcing managers and practitioners in improving their outsourcing activities. This chapter includes proposals for outsourcing managers and practitioners and also the recommendations for further research work.

9.1 PROPOSALS FOR OUTSOURCING MANAGERS AND PRACTIONIONERS

This research study may help managers and practitioners to understand that outsourcing of manufacturing is different from normal in-house manufacturing activities, and also from normal company and supplier relationships. The information collected, using questionnaires and interviews, provide proof that the outcome of the research is important for outsourcing managers and practitioners. The majority of the respondents told that they did not have any decision models to follow for managing outsourcing activities. They have been managing their outsourcing activities according to their expertise and experience. The respondents also agreed that the proposed decision models are helpful to them, in order to better understand the outsourcing operations, and for improving them. The managers acknowledged that during reviewing of models, they found the discussions around weaknesses in outsourcing operations useful for them to understand the problems in the outsourcing of manufacturing.

The author proposed to managers to avoid managing outsourcing operations based on their previous in-house manufacturing experience alone. They should reorganise their thinking

for managing a new type of activities (organisation of outsourcing operations) with another company.

The author also proposed to managers to exploit the information about problems in outsourcing of manufacturing, and plan to improve outsourcing operations. The outsourcing managers and practitioners may benefit from the information and modify their practices in a way that aids them in eliminating or mitigating weaknesses/defects/problems, which occur during each of the outsourcing activities. Furthermore, the outsourcing decision models are formulated to provide tools for decision-making. The improvement in outsourcing operations is translated as a reduction in outsourcing operational costs, and an increase in its benefits and success.

9.2 RECOMMENDATIONS FOR FURTHER WORK

This research study has provided in-depth knowledge about the outsourcing of small and medium sized manufacturing companies. A number of decision models for outsourcing of manufacturing have been structured, and each model was formulated with the objective of achieving success in the outsourcing of small and medium sized manufacturing companies. The recommendations for future research work are proposed as follows:

Improvement of Outsourcing Decision Models: The outsourcing decision models were formulated using information collected from a literature survey, and from manufacturing companies practising outsourcing. During the testing of outsourcing decision models, it was found that there is still room for improvement of the outsourcing decision models. Therefore, undertaking research that is aimed at identification of weaknesses and improving the outsourcing decision models is proposed. The decision models must be upgraded to a level which is able to correct any newly-encountered weakness/defect.

Comparing the ways in which managers in different industrial sectors have been managing the outsourcing of manufacturing activities, and mitigating outsourcing problems, is proposed. It is also suggested that some academics undertake research for providing possible solutions in order to mitigate problems.

***Extension of Outsourcing Decision Models*:** The outsourcing decision models were structured for carrying out outsourcing activities in the manufacturing sector (small and medium sized companies). It is advisable to apply the decision models in other industries, in order to test their appropriateness. Comparing the outsourcing of manufacturing operations with outsourcing operations in other fields is also proposed. Hence, the research on outsourcing could be extended to outsourcing of product design and development.

***Expansion* of *Outsourcing Decision Models*:** Although the outsourcing decision models were reviewed individually on various manufacturing companies which have been outsourcing, it is proposed to expand the research in outsourcing of manufacturing activities, with the objective of indentifying any possible weaknesses, and to update the decision models accordingly.

***Research into Multi-Sourcing*:** The outsourcing decision models were formulated using information collected from literature survey and manufacturing companies using questionnaire and interviews. Positive feedbacks were provided when these models were presented to the managers of Newton Equipment, Totalli SRL and Sonic Enterprise.

Since multi-sourcing of manufacturing has not been part of this thesis. Further investigation is proposed into multi-sourcing and the factors that may contribute to the success of multi-sourcing.Thus, after the successful development of outsourcing decision models during this research, these models could be further developed to serve as multi-sourcing models.

***Ranking of Problems in Outsourcing of Manufacturing*:** Ranking outsourcing problems, according to their threat level (seriousness), is suggested. The research on outsourcing of manufacturing would benefit from the information, as to which ones are the most common and the most serious problems that occur in the outsourcing of manufacturing. So that appropriate actions could be prioritised according to their seriousness.

***Optimisation of Outsourcing*:** Further research may be directed towards optimisation of outsourcing. In the initial stage of the optimisation process, the outsourcing is subjected to

constraints. At a later stage, the optimisation may be extended to obtain the best compromise between the best quality, the minimum cost and the minimum lead time.

***Quantitative Model for Managing Short-term Outsourcing Activities*:** A quantitative model for managing short-term outsourcing activities could be formulatted by employing theory of constraints (TOC) with traditional costing (volume-based costing) and/or activity-based costing (ABC).

***Qualitative Model to Facilitate Long-term Managerial Decisions*:** A qualitative model for managing long-term outsourcing decisions could be formulated by combining outsorcing process with Lean philosophy. The lean could infuse continuous improvement as an integral part of the outsourcing model.

***Stochastic Parameters*:** The stochastic parameters may be included in the models to address the unexpected / random trend of the market.

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APPENDIX A: QUESTIONNAIRE COVERING LETTER

Dear Sir/Madam,

Reference: <u>Questionnaire on Improving Outsourcing Operations</u>

I am requesting your assistance for my postgraduate research in carrying out a survey on outsourcing operations. Your response will be most useful for developing a framework for improving outsourcing operations for manufacturing companies. This will have a positive impact on organisations practising outsourcing, or planning to outsource/transfer their manufacturing.

Attached please find a questionnaire. I would be most grateful if you could spare some moments to complete and return this to me.

Please be assured that all the information provided will be used for research purposes, and in accordance with the data protection act.

If you have any enquiries regarding this survey, please do not hesitate to contact me. Let me take this opportunity to thank you in advance for your assistance in this matter.
I look forward to your earliest response.

Yours sincerely,

(Adnan Adnan)

Postgraduate Researcher
Kingston University

APPENDIX B: QUESTIONNAIRE 1

Name:
Company/Supplier Name:
Supplier Tier: Tier-1/Tier-2/Tier-3/……/Lower Tier
Number of employees:
Products manufactured:

Please tick as appropriate.

Q 1: The Company has transferred/outsourced ___ to the supplier
- **a) part of its components manufacturing**
- **b) all of its components manufacturing**

Q 2: <u>Degree of Importance</u>
Please mark the appropriate on the scale of 5; if not sure mark '?'
1= Most Important 5= Least Important

Having lower manufacturing cost than competitors___
Faster deliveries than competitors___
Superior product quality than competitors___

Q 3: <u>Reasons for the delay during order processing</u>

Low priority assigned to the job __	**Yes/No**
Dedication to other businesses __	**Yes/No**
Supplier does not have the capability to cope with the order __	**Yes/No**
Supplier does not have the capacity to cope with the order __	**Yes/No**

Q 4: Average delays in delivery are? __
a) 1-6 Hours b) 1-2 days c) 3 days – 1Week d) __?

Q 5: Delay due to delivery system is __ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 6: Delay in supplying orders in time is __ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 7: Delay due to incomplete specification in order request is__ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 8: Delay due to incorrect information in delivery notes is__ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 9: Delay due to error in invoicing is__ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 10: Delay due to incomplete delivery is__ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 11: Delay due to error in delivery destination/location is__ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 12: Delay due to error in delivering to right person is__ orders?
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 14: Change in order size is __?
a) None - 10% b) between 11 - 20% c) between 21 - 50% d) More than 50%

Q 15: Does the delivery system require new equipment? __ Yes/No

Q 16: Does the delivery system require new software? __ Yes/No

Q 17: Does the delivery system require additional workforce? __ Yes/No

Q 18: The company relationship with the supplier is? ___
1) Easy 2) Difficult 3) Inconsistent

Q 19: Does the supplier understand the business requirements of the customer? ___
Yes/No

Q 20: Explain the communication and monitoring process between the company and the supplier? ___ 1) Very Easy 2) Easy 3) Difficult 4) Uncomfortable

Q 21: Does the company or the supplier have a training programme to improve inter-communication and monitoring? ___

a) **Already introduced**
b) **In a process of introducing**
c) **Does not have and not intending**
d) **Planning to introduce one**

Q 22: Quality of the components supplied qualifies ISO9000? ___ Yes/No

Q 23: How frequent is the supply of defective components to the customer? ___
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 24: Numbers of defective components supplied are? ___
a) None – 1% b) between 1% - 5% c) between 5% - 10% d) More than 10%

Q 25: Is the supplier practising quality-control programmes effectively? ___
Yes/No

Q 26: Are defective components included in the order so as to complete the order quantity? ___ Yes/No

Q 27: Is there any form of penalty system introduced for despatching poor-quality components? ___ Yes/No

Q 28: Can supplier deliver better-quality components at higher price? ___
Yes/No

Q 29: To reduce defective components delivered, supplier ___

a) **Is considering implementing improvement plan**
b) **Is trying to implement improvement plan**
c) **Is neither intending nor planning**

Q 30: Is there any confidentiality agreement between the company and the supplier? ___
Yes/No

Q 31: Is the design of the equipment new and cannot be exposed to general knowledge? ___
Yes/No

Q 32: Is the technology used to manufacture the components patented, and then who owns or has bought the patent rights? ___
a) Supplier b) Customer c) Both

Q 34: The supplier is collaborating with many other companies and the information leakage during the meetings is ___

a) accidental b) deliberate c) systematic

Q 35: Is there any chance that the information could be sold by the employees to the competitors? ___ Yes/No

Q 36: Could the information leakage be due to lack of security in the communication system? ___ Yes/No

Q 37: In order to minimise the information leakage the supplier ___

a) is considering implementing a training programme
b) is implementing a training programme
c) does not care, as it is not part of business strategy

Quality and Performance

Please mark the appropriate, if employing the following manufacturing/management tool. If not sure about the management tool, please mark '?'.

1= fully implemented 2= partially implemented 3= beginning to implement 4= do not have

TQM (Total Quality Management)

TQC (Total Quality Control)

Zero defect programmes

Kaizen

ISO 9000/BS 5750

Pull System

SPC (Statistical Process Control)

Kaizen

Plant within Plant

Cellular Layout

TPM (Total Preventive Maintenance)

LM (Lean Manufacturing)

Benchmarking

Employee organised its team

In-house training programme

Job rotation

Technologies and Techniques

Please tick, if using the following manufacturing techniques. If not sure about manufacturing techniques, please mark '?'

NC (Numeric Control)

CNC (Computerised Numeric Control)

DNC (Distributed Numeric Control)

GT (Group Technology)

IR (Industrial Robots)

FMC (Flexible Manufacturing Cells)

FMS (Flexible Manufacturing Systems)

CIM (Computer Integrated Manufacturing)

AS/AR (Automated Storage and Retrieval)

AMH (Automated Material Handling)

ADS (Automated Delivery System)

MRP (Material Requirement Planning)

MRP II (Material Requirement Planning II)

Education and Training

Please tick as appropriate.

Is there a training programme for employees ____?

Is there a management-training programme__?

Is there a quality-control training programme___?

Did employees ever attend any training programme in last 12 months___?

None___ Less than 1day___ 1 to less than 2 days___ 2 to less than 5 days___
5 to less than 10 days___ 10 days or more___

Supplier Selection Criteria

Please tick as appropriate. (Please suggest your own)

Cost	Quick Delivery	Delivery Reliability	Communication Relationship
Quality	Cost of Production	Quality Control	Price
ISO 9000	Delivery flexibility	Quality reliability	Cost of Ordering
Delivery	Delivery Condition	Information Systems	On-Time Delivery
Shipment	Shipment Quality	Compliance with Packaging Standards	Financial Operation ability
Financial stability	Management capability	Management commitment	Continuous Improvement
Process Improvement	Performance Image	Performance Measurement	Organisational Structure
Organisation Environmental	Claims handling	Problem Solving	Capacity Utilisation
Production Capacity	Reputation	Regulatory Knowledge	Understanding of pertinent law
Intellectual Property Protection	Process Ownership	Personnel Capability	Process Capability
Knowledge and ability	Training	Cooperation & partnership	Link with customers/ suppliers
Technical expertise	Security	Supply lots	Market share
Responsiveness	Environmentalal concern	Political Stability	Competitive Advantage
Product rejection ratio	Flexibility	Human Resources	Negotiability

APPENDIX C: QUESTIONNAIRE 2

Preference:

A is equally preferred to B	1
A is weakly preferred to B	2
A is slightly preferred to B	3
A is less moderately preferred to B	4
A is moderately preferred to B	5
A is highly preferred to B	6
A is strongly preferred to B	7
A is very strongly preferred to B	8
A is extremely preferred to B	9

Please fill in the preference column appropriately

A	Preference	B
Business and Intellectual property laws	1	Business and Intellectual property laws
Technology and Manufacturing ability		Business and Intellectual property laws
Financial operations ability		Business and Intellectual property laws
Reputation		Business and Intellectual property laws
Management and Business Professionalism		Business and Intellectual property laws
Effective Cost		Business and Intellectual property laws
On-time Delivery		Business and Intellectual property laws
Quality		Business and Intellectual property laws
Financial operations ability		Technology and Manufacturing ability
Reputation		Technology and Manufacturing ability
Management and Business Professionalism		Technology and Manufacturing ability
Effective Cost		Technology and Manufacturing ability
On-time Delivery		Technology and Manufacturing ability
Quality		Technology and Manufacturing ability
Reputation		Financial operations ability
Management and Business Professionalism		Financial operations ability
Effective Cost		Financial operations ability
On-time Delivery		Financial operations ability
Quality		Financial operations ability
Management and Business Professionalism		Reputation
Effective Cost		Reputation
On-time Delivery		Reputation
Quality		Reputation
Effective Cost		Management and Business Professionalism
On-time Delivery		Management and Business Professionalism
Quality		Management and Business Professionalism
On-time Delivery		Effective Cost
Quality		Effective Cost
Quality		On-time Delivery

Note: In case B is preferred to A, please use reciprocals of number

APPENDIX D: QUESTIONNAIRE 1 DATA ANALYSIS RESULTS

The data collected through first questionnaire survey was input into SPSS 10.1 package. The results of the analysis are given as follows:

The survey analysis shows that 8 respondent companies have declared lower cost 'important' than competitors. However, 7 respondent companies have declared lower cost 'Most Important' and 'Very Important' respectively. Figure B.1 shows a company's requirement for lower manufacturing cost than competitors.

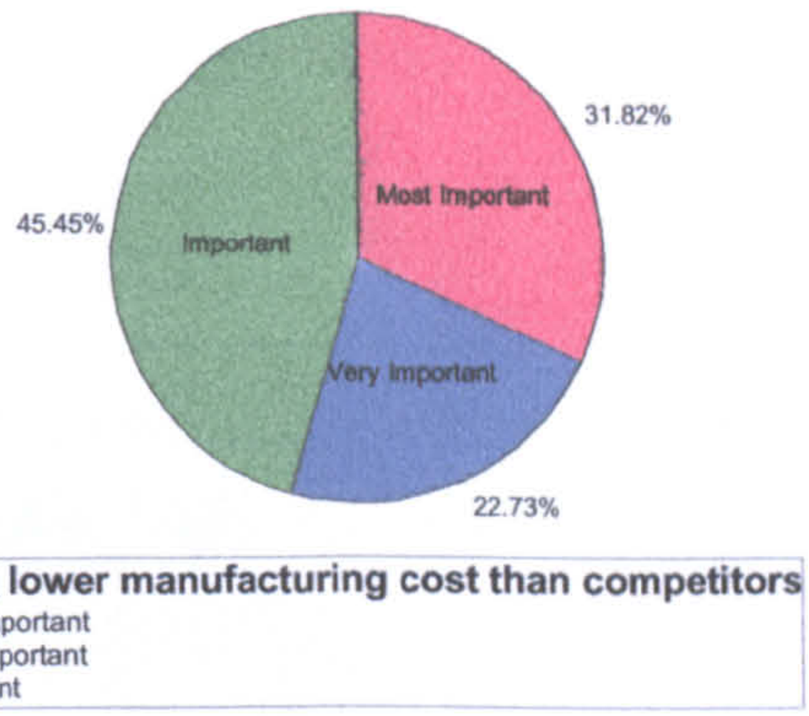

Figure B.1: Outsourcer's requirement for lower manufacturing cost than competitors

Figure B.2 shows that 10 respondent companies have declared fast deliveries 'important' and 8 respondent companies have declared fast deliveries 'Very important' than competitors. However, only 4 respondent companies have declared fast deliveries 'Most important' than competitors.

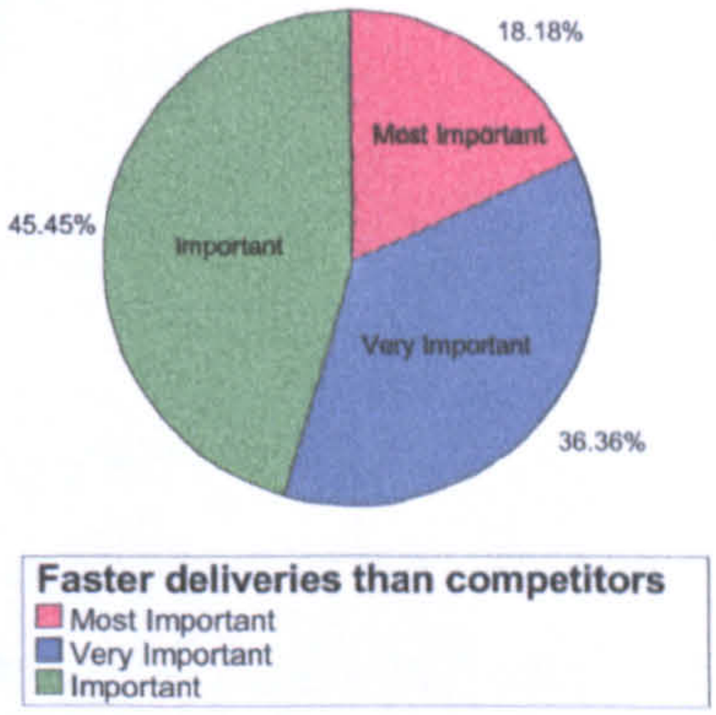

Figure B.2: Outsourcer's requirement for faster delivery than competitors

The survey analysis shows that 1% - 5% of the deliveries were delayed in the case of 72.7% of the respondent companies. There was only one company that had experienced a

delay in deliveries which was greater than ten percent. The majority of the experts agreed that 1% - 5% of delay in delivery is taken as a benchmark.

Figure B.3: Delay in delivery due to supplying orders

Figure B.4 shows that 13 of the surveyed companies have encountered 1% - 5% error in '*order request*' which contributed to '*delay in delivery*'. However, one company reported a percentage error >10% in the '*order request*'.

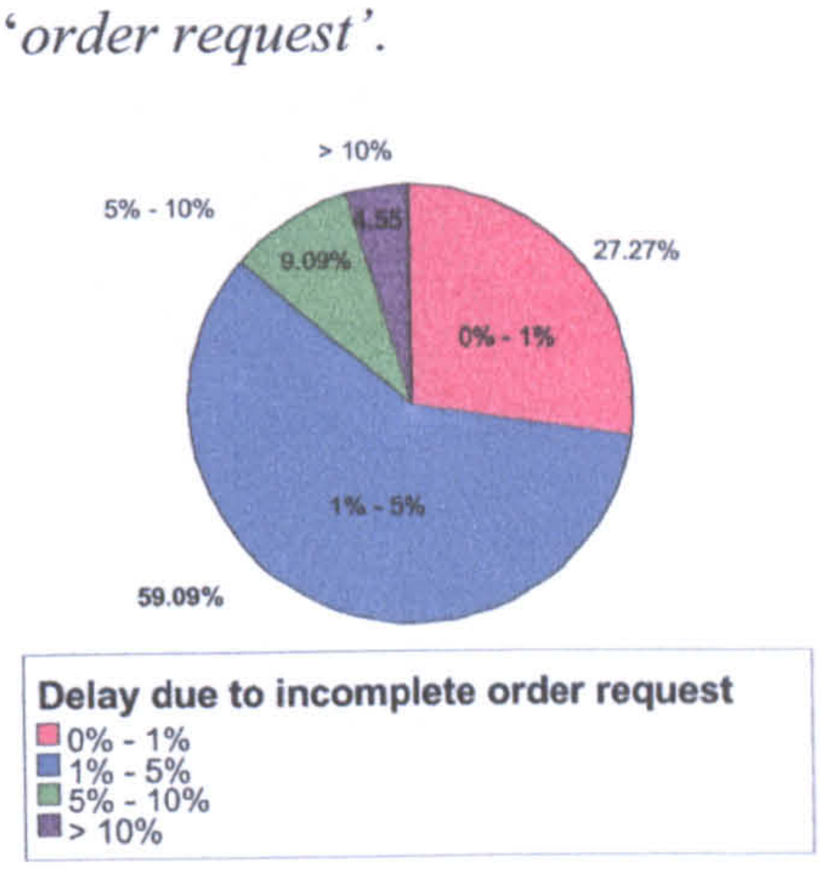

Figure B.4: Delay in delivery (supply) due to error in order request

The '*incomplete delivery*' (order size/ quantity) is another factor that contributes to delay in delivery. Due to incomplete delivery, it is not possible to complete the assembly of the final products or batch of the products. Figure B.5 shows the delay in supply/ delivery due to incomplete delivery.

The survey analysis shows that 1% - 5% of the deliveries were incomplete in the case of ten respondent companies. Similarly ten of the surveyed companies responded that 0% -

1% of the deliveries were incomplete. In order to set up a benchmark, the managers of the companies were consulted. The majority of the respondents agreed that 1% - 5% of the incomplete deliveries are acceptable in order to select a supplier.

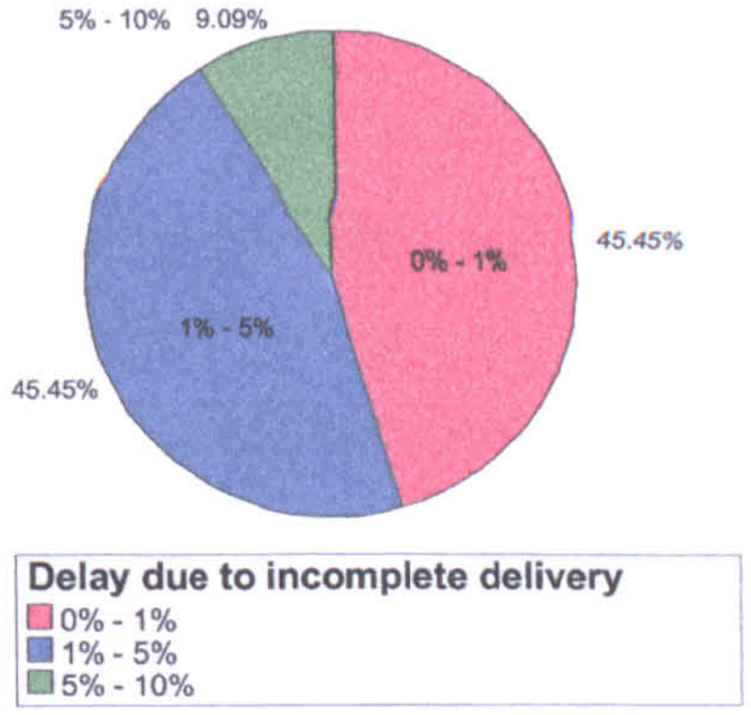

Figure B.5: Delay in delivery/ supply due to incomplete delivery

The mistakes or error in *delivery destination* also contribute towards *delay in delivery* of orders. It is found out that the delivery is sent to the same company and due to some errors, it is delivered to the other branch. For example, one of the respondent companies told that the steel billets were ordered for London branch and they were delivered at the other branch in Cambridge. Sometimes, the invoice address and delivery addresses are interchanged due to some errors.

Figure B.6 shows that 0% - 1% of the deliveries were sent to the wrong destination in case of 68.2% of the respondent companies. Only three of the respondent companies reported errors in destination greater than 10%.

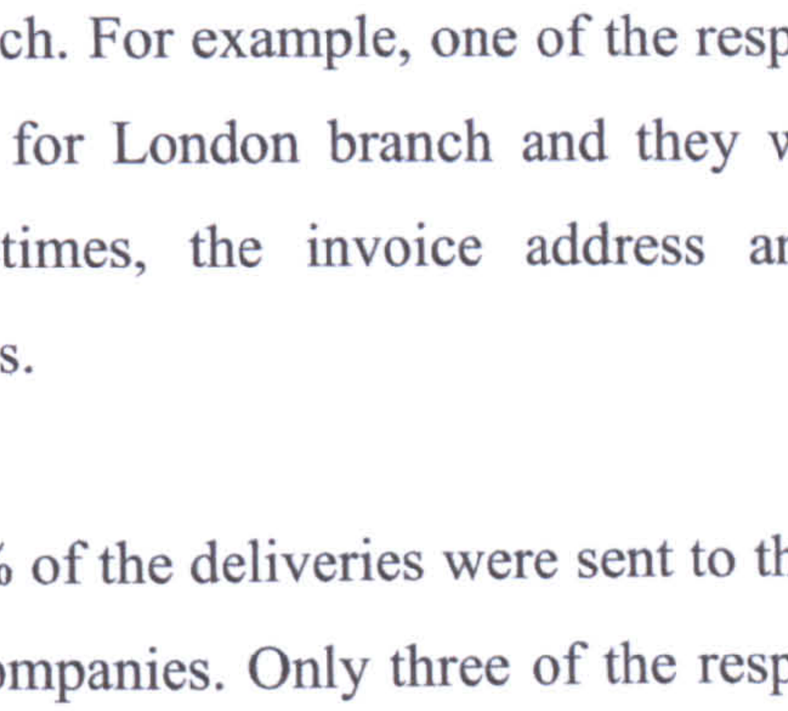

Figure B.6: Delay in delivery/ supply caused by 'error in delivery destination'

The errors in *delivery note* or incorrect *delivery note* is another factor that contributes *delay in delivery*. When the delivery is received, its contents are matched with the delivery note. If the contents of the delivery and the delivery note do not match, the discrepancies are reported back to the supplier (outsourcee).

The survey analysis shows that 0% - 1% of *incorrect delivery notes* in case of 9 respondent companies. However, 8 respondent companies reported 1% - 5% of *incorrect delivery notes*. After discussion, majority of the managers of the respondent companies agreed that 0% - 1% of errors in *delivery notes* could be set as a standard for supplier selection. The *delay in delivery* due to *incorrect delivery note* is shown as Figure B.7.

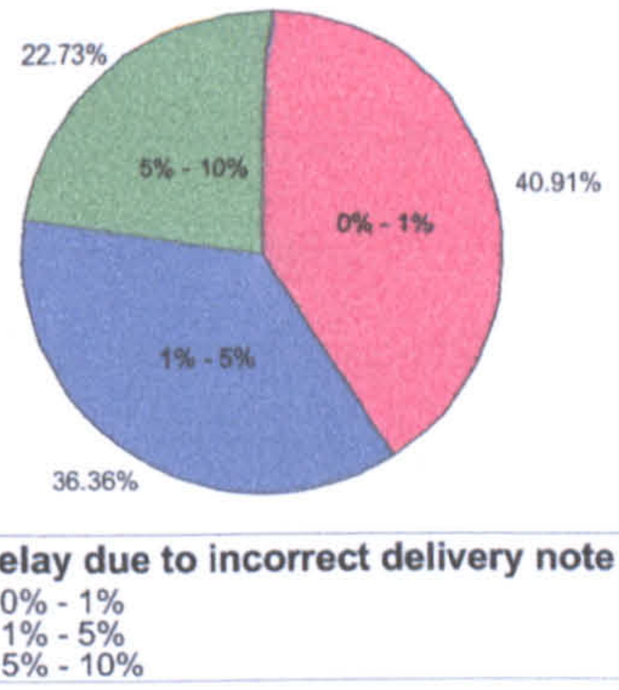

Figure B.7: Delay in delivery/ supply due to error in delivery note

The *errors or mistakes in invoice* are also responsible for *delays in delivery*. When the invoice is received, it is matched with delivery note for contents. The prices charged on the invoice are matched with the prices agreed on the contracts and totals are also checked. In case of any mistakes, these are reported back to the supplier (outsourcee). Sometimes the further orders are not processed unless the mistakes in the invoice are corrected.

The survey analysis shows that majority of the respondent companies have encountered 0% - 1% *mistakes/ errors in invoice* which contributed to the *delay in delivery*. However, 7 companies have reported 1% - 5% *errors in the invoice*. In-depth discussion with the experts of the companies revealed that invoicing is a complex issue. Most of the companies agreed that they have been investing a lot of effort on invoice matching. Sometimes the errors can be rectified easily; otherwise it becomes complicated and involves raising internal and external credit notes. The *delay in delivery* due to *errors in invoice* is presented in Figure B.8.

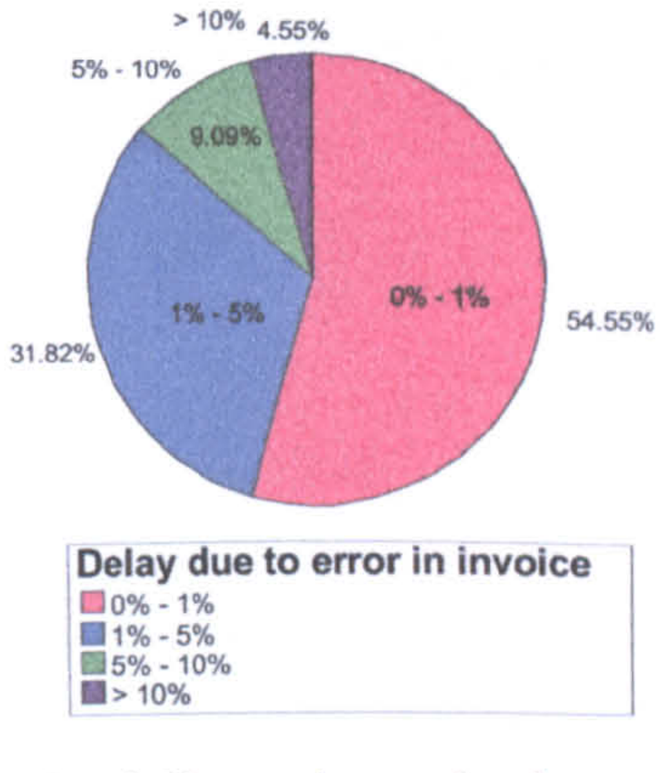

Figure B.8: Delay in delivery/ supply due to error in invoice

The literature survey lacks empirical information about the *delay in delivery* in terms of time units. Therefore, the questionnaire survey is designed to find out the *delay in delivery*. Figure B.9 shows that 50% of the respondent companies have encountered 25-48 hours of delay in delivery. However, 36% of the respondent companies have reported 49-168 hours of delay in delivery. In outsourcing, most of the manufacturing suppliers (outsourcee) are based abroad. Therefore, a supplier who can supply with less than 48 hours delay is considered as the most suitable one. The managers of the companies have recommended that 49-168 hour delay should be acceptable. The analysis shows that the *delay in delivery* can be reduced with experience, as the relationship amongst the suppliers and the company matures.

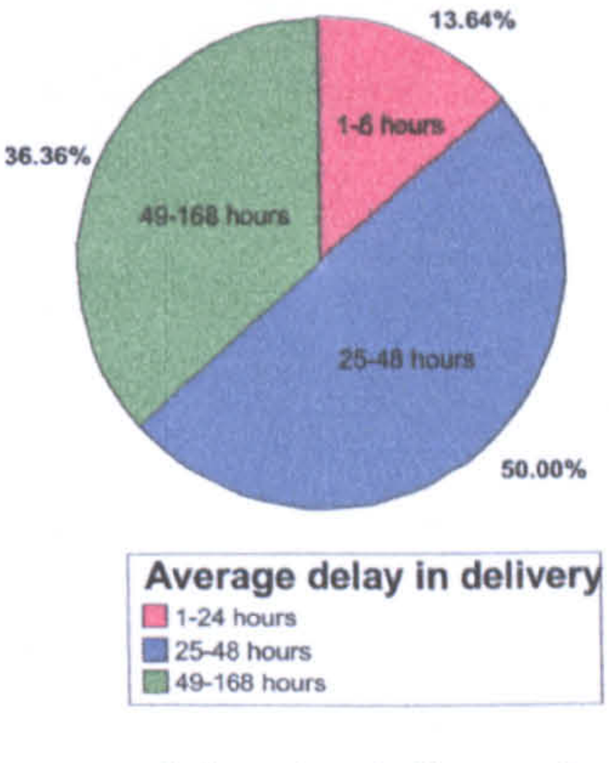

Figure B.9: Average delay in delivery/ supply (percentage)

There are a number of reasons for *delay in delivery*. One of the reasons of the *delay in delivery* could be that the supplier (outsourcee) is dedicated to the other customers (companies). It is enquired whether the delay in delivery is because the other companies (outsourcers) are given the highest priority.

The survey analysis shows that 50% of the respondent companies declared that the *delay in delivery* is because the supplier prefers other companies. It is also revealed during discussion that unexpected supply of orders to other companies. The results of the survey analysis are shown as Figure B.10.

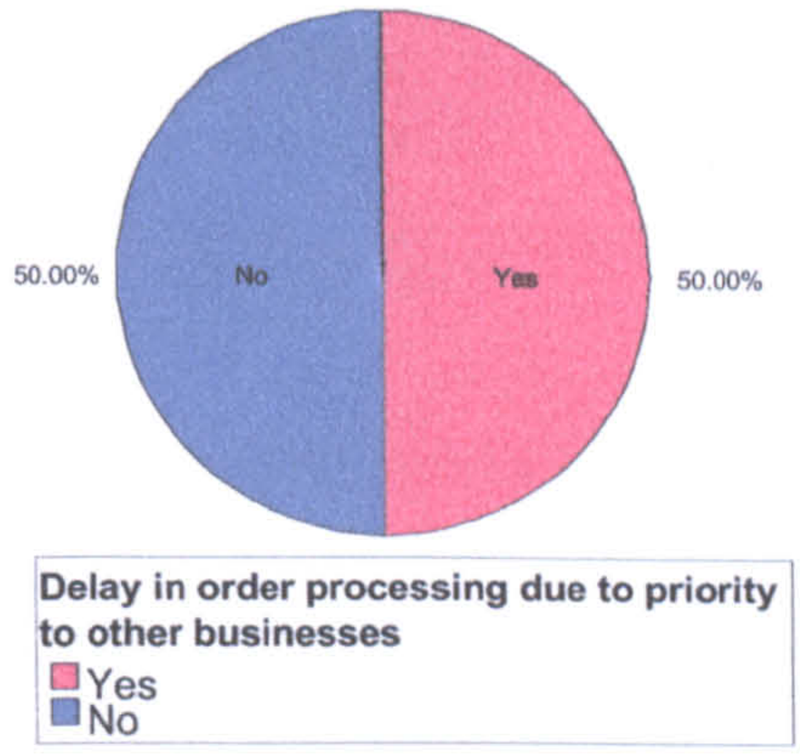

Figure B.10: Delay in delivery because of priority given to other businesses

There is a possibility that the supplier (outsourcee) may not have the capability to manufacture the products in time. Since there is insufficient information available on *delay in delivery* due to outsourcee lacks manufacturing capability. Because of this, the question is formulated in order to collect empirical data. During detailed investigation it was found out that it is difficult to answer this question because of the location of the supplier. Some of the senior managers of the company advised that in order to access the capability, one should visit personally or higher a third party consultant.

Figure B.11 shows that only 4 of the respondent companies reported that their manufacturers (suppliers) lack capability of manufacturing components in time. However, majority of the respondent companies reported that their supplier have the capability of manufacturing the components in time.

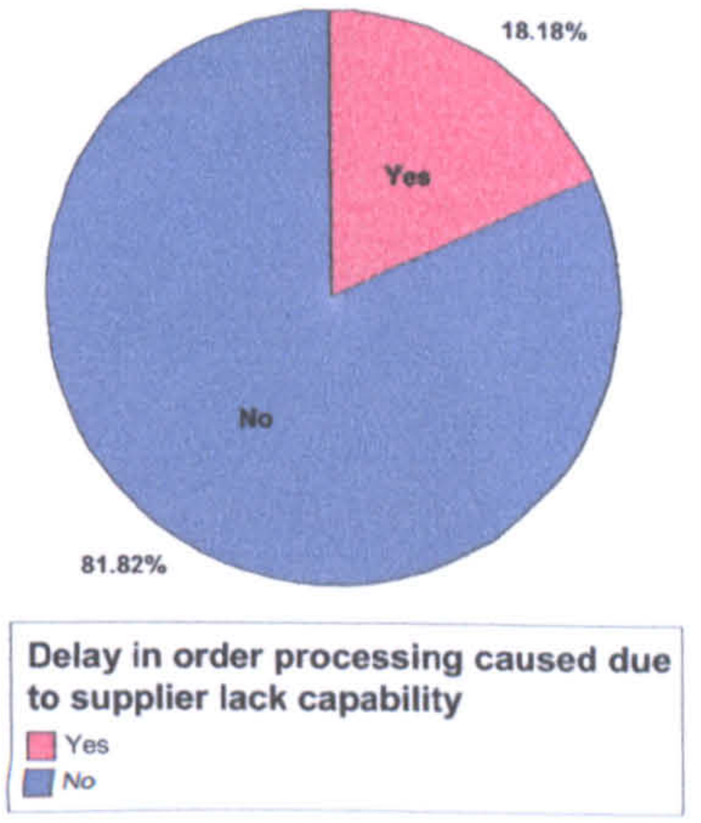

Figure B.11: Delay in delivery/ supply caused due to outsourcee lacks capability

The *quality* is one of the most important criteria for supplier selection. It is also an important factor that is included in improvement models. Figure B.12 shows that 18 respondent companies declared that they have been implementing the quality control programme effectively. However, only 4 respondents companied reported that they are unable to implement the *quality control programme* effectively.

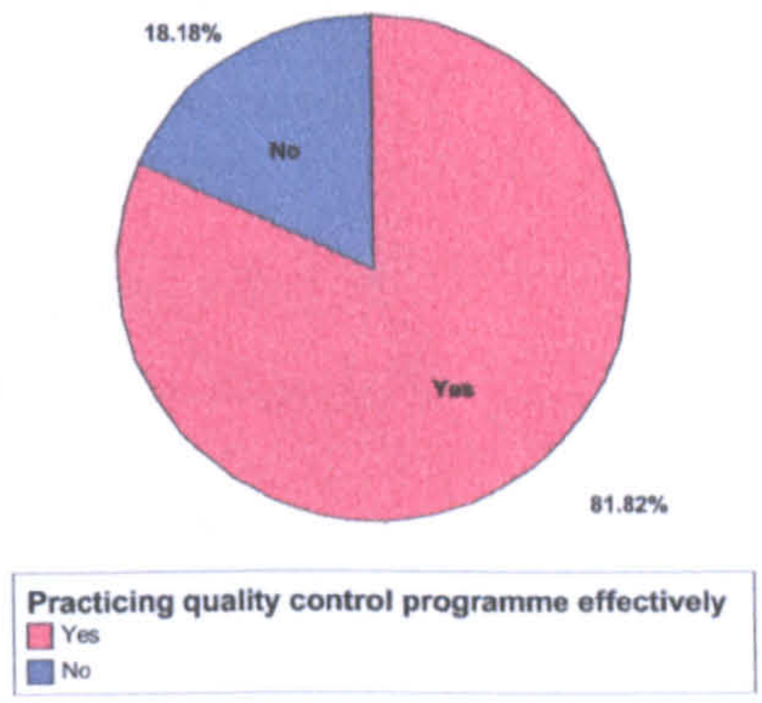

Figure B.12: Companies practicing quality control programme effectively (percentage)

The *quality* of the components manufactured is determined by their conformance with the ISO 9000 standards. The majority of the managers agreed that ISO 9000 certification should be asked from the suppliers, in spite of sending own expert to check the quality.

Figure B.13 shows that 19 respondent companies agreed that their components conforms ISO 9000. In detail discussion with companies revealed that majority of their suppliers are conforming ISO 9000. There are some exceptional cases when the suppliers are not

conforming ISO 9000 standards. In that case, the company works with the supplier and facilitates in achieving ISO 9000 certification.

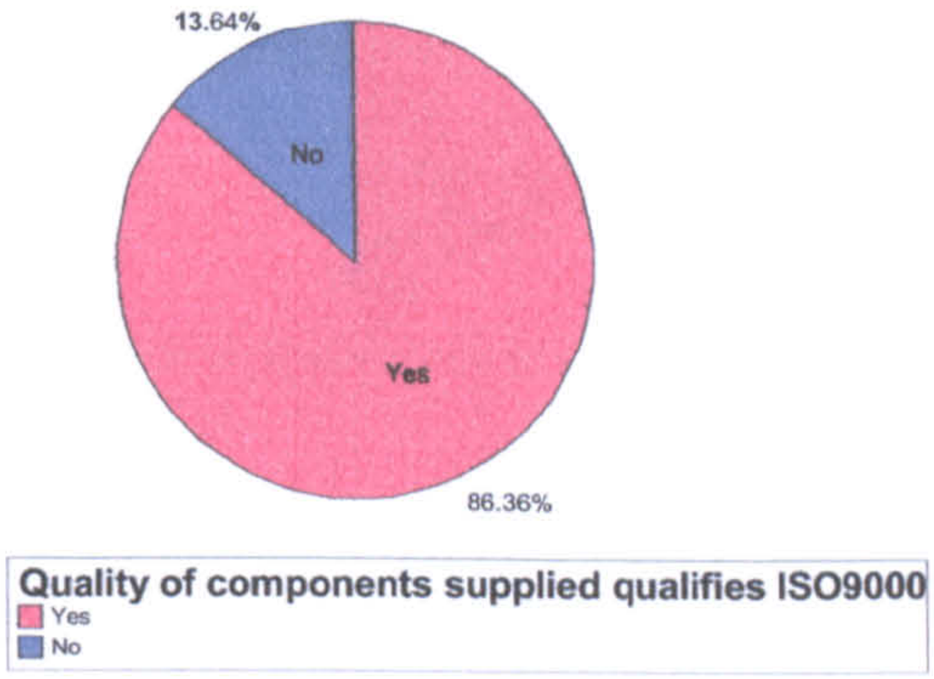

Figure B.13: Percentage of supplied components conforming ISO 9000

By comparing the results of surveyed analysis listed in Table B.1, it is apparent that percentage of the components manufactured conforming ISO 9000 standards is proportional to the percentage of suppliers practicing quality control effectively. One of the managers added that if a company implements quality control programme, it can manufacture components conforming ISO 9000 without any additional investment.

Description	**Yes**	**No**
Practicing quality control effectively	81.82	18.18
Quality of components conforms ISO 9000	86.36	13.64

Table B.1: Comparison between quality control programme & supplied components

Figure B.14 shows that 1% - 5% of the components were defective in case of 15 respondent companies. However, only three companies reported 5% - 10% defective components. The majority of the managers suggested that it would be appropriate to select manufacturers as suppliers, which have less than 5% of defective components. During discussion, it was asked from the managers, as how to find out the number of defective components supplied. There was a mix response. Some managers advised that the manufacturers should be asked to manufacture some sample components. The quality of those components determines the capability of those manufacturers to deliver quality. Some of the managers advised that the manufacturers should be visited before signing the contract. Another group of managers suggested external consultants should be hired.

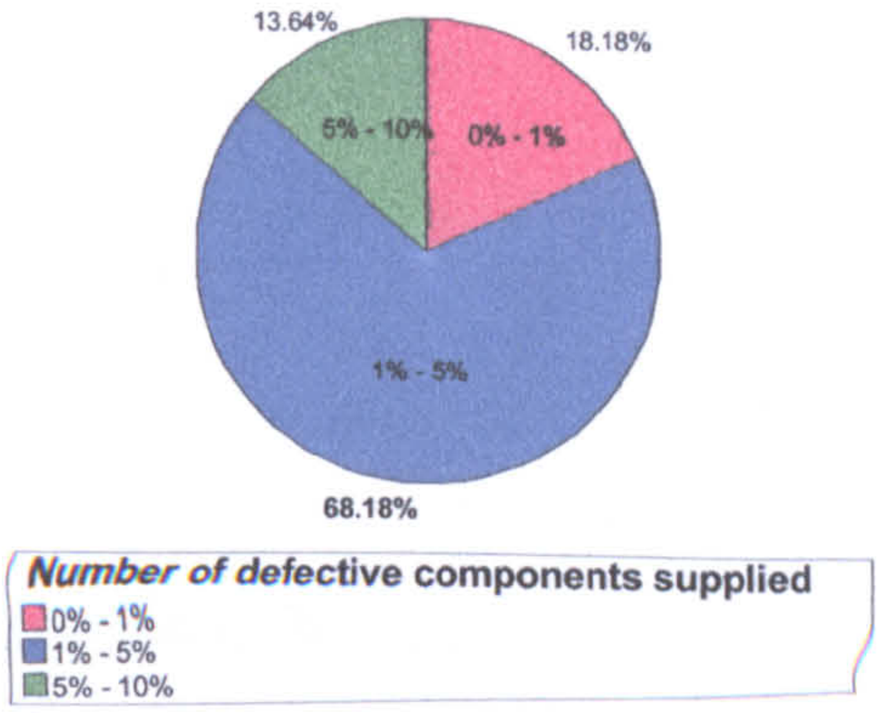

Figure B.14: Number (Percentage) of supplied defective components

The survey analysis shows that majority of the respondent companies have encountered 1% - 5% frequency of defective components. Only three of the respondent companies reported 5% - 10% frequency of defective components. Figure B.15 shows the percentage frequency of delivered/ supplied defective components. In questionnaire the option, frequency of defective components delivered/ supplied >10% was not included. The manufacturing companies having frequency of defective components >10% are not be considered for supplier (outsourcee). The results of the survey analysis were discussed with the mangers of the companies. It was agreed that frequency of defective components less than five percent is acceptable. However frequency of defective components delivered/ supplied less than 5% is considered as the most suitable.

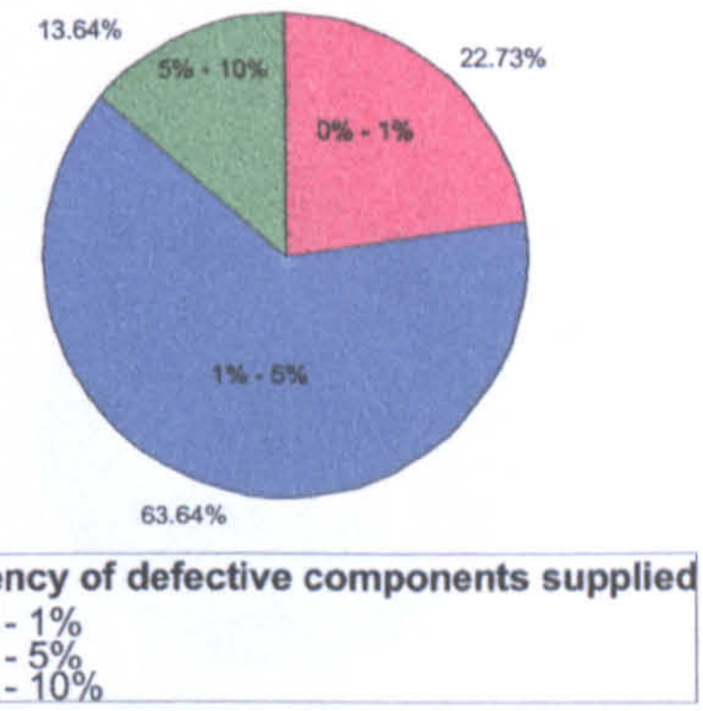

Figure B.15: Percentage frequency of delivered/ supplied defective components

Table B.2 shows that percentage number of defective components supplied and percentage frequency of defective components supplied is approximately same between the 0% - 5% interval.

	0% - 1%	1% - 5%	0% - 5%
No of defective components supplied	18.2	68.2	86.4
Frequency of defective components supplied	22.7	63.6	86.3

Table B.2: Comparison between numbers and frequency of defective components

Figure B.16 shows that 15 respondent companies expect to acquire better quality at higher cost.

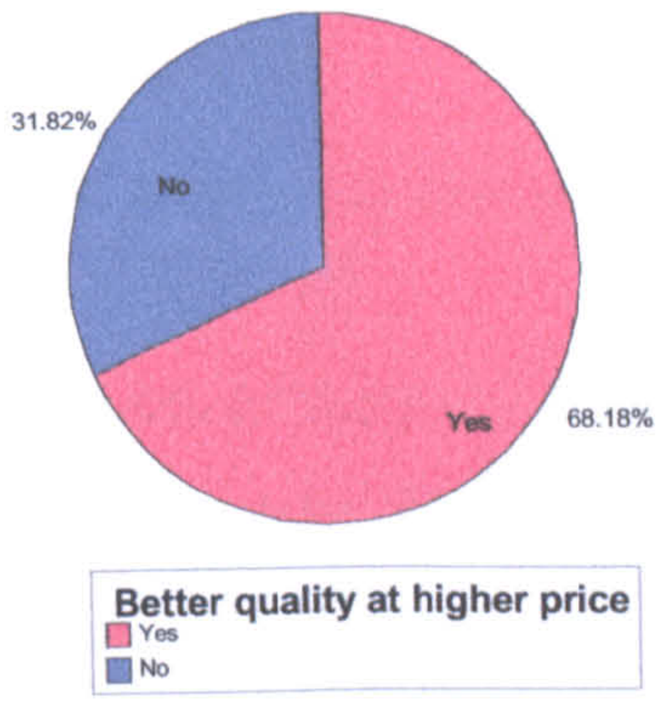

Figure B.16: Outsourcer's perception of acquiring better quality at higher price

Figure B.17 shows that 12 of the respondent companies consider quality 'very important' and 8 of the respondent companies consider it 'most important' than competitors.

Figure B.17: Outsourcer's requirement for superior product quality than competitors

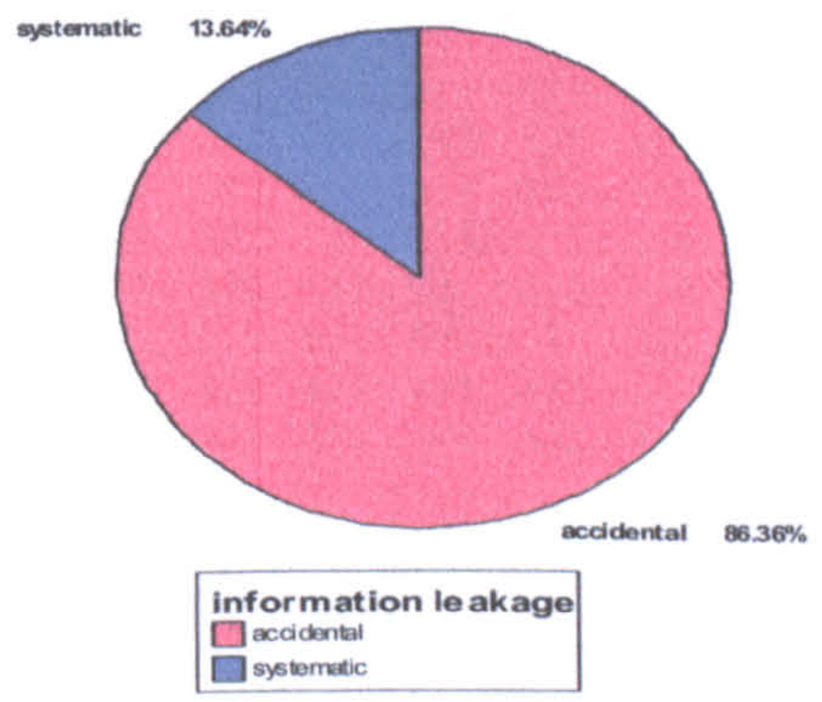

Figure B.18: Reasons of information leakage

The survey result revealed that 86.4% of the total information leakage is accidental and only a small fraction could be due to mistake. The companies did not have the information secrecy system in operation.

APPENDIX E: QUESTIONNAIRE 2 DATA ANALYSIS RESULTS

$$V_{Newton} = \begin{bmatrix} \mathbf{1} & 1/4 & 1/2 & 1/5 & 1/3 & 1/4 & 1/4 & 1/5 \\ 4/1 & \mathbf{1} & 1/3 & 1/5 & 1/4 & 1/4 & 1/4 & 1/5 \\ 2/1 & 3/1 & \mathbf{1} & 1/2 & 1/3 & 1/3 & 1/3 & 1/4 \\ 5/1 & 5/1 & 2/1 & \mathbf{1} & 1/5 & 1/5 & 1/4 & 1/5 \\ 3/1 & 4/1 & 3/1 & 5/1 & \mathbf{1} & 1/5 & 1/4 & 1/5 \\ 4/1 & 4/1 & 3/1 & 5/1 & 5/1 & \mathbf{1} & 1/4 & 1/5 \\ 4/1 & 4/1 & 3/1 & 4/1 & 4/1 & 4/1 & \mathbf{1} & 1/4 \\ 5/1 & 5/1 & 4/1 & 5/1 & 5/1 & 5/1 & 4/1 & \mathbf{1} \end{bmatrix}$$

Newton	Organisational Environmental & laws	Technology & Manufacturing ability	Financial operations ability	Reputation	Management & Business Professionalism	Effective Cost	On time Delivery	Quality
Organisational Environmental & laws	**1.0000**	0.2500	0.5000	0.2000	0.3333	0.2500	0.2500	0.2000
Technology & Manufacturing ability	4.0000	**1.0000**	0.3333	0.2000	0.2500	0.2500	0.2500	0.2000
Financial operations ability	2.0000	3.0000	**1.0000**	0.5000	0.3333	0.3333	0.3333	0.2500
Reputation	5.0000	5.0000	2.0000	**1.0000**	0.2000	0.2000	0.2500	0.2000
Management & Business Professionalism	3.0000	4.0000	3.0000	5.0000	**1.0000**	0.2000	0.2500	0.2000
Cost Effectiveness	4.0000	4.0000	3.0000	5.0000	5.0000	**1.0000**	0.2500	0.2000
On time Delivery	4.0000	4.0000	3.0000	4.0000	4.0000	4.0000	**1.0000**	0.2500
Quality	5.0000	5.0000	4.0000	5.0000	5.0000	5.0000	4.0000	**1.0000**
	28.0000	26.2500	16.8333	20.9000	16.1167	11.2333	6.5833	2.5000

Newton	Organisational Environmental & laws	Technology & Manufacturing ability	Financial operations ability	Reputation	Management & Business Professionalism	Effective Cost	On time Delivery	Quality	Average
Organisational Environmental & laws	0.0357	0.0095	0.0297	0.0096	0.0207	0.0223	0.0380	0.0800	0.0307
Technology & Manufacturing ability	0.1429	0.0381	0.0198	0.0096	0.0155	0.0223	0.0380	0.0800	0.0458
Financial operations ability	0.0714	0.1143	0.0594	0.0239	0.0207	0.0297	0.0506	0.1000	0.0588
Reputation	0.1786	0.1905	0.1188	0.0478	0.0124	0.0178	0.0380	0.0800	0.0855
Management & Business Professionalism	0.1071	0.1524	0.1782	0.2392	0.0620	0.0178	0.0380	0.0800	0.1094
Cost Effectiveness	0.1429	0.1524	0.1782	0.2392	0.3102	0.0890	0.0380	0.0800	0.1537
On time Delivery	0.1429	0.1524	0.1782	0.1914	0.2482	0.3561	0.1519	0.1000	0.1901
Quality	0.1786	0.1905	0.2376	0.2392	0.3102	0.4451	0.6076	0.4000	0.3261
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

$$W_{Newton} = [0.0307 \quad 0.0458 \quad 0.0588 \quad 0.0855 \quad 0.1094 \quad 0.1537 \quad 0.1901 \quad 0.3261]^T$$

Priority Weight Vectors of London Packaging Limited, Kenth Engineering and Sonic Enterprise is given as follows:

$$W_{LPg} = [0.0323 \quad 0.0499 \quad 0.0547 \quad 0.0707 \quad 0.1078 \quad 0.1346 \quad 0.2052 \quad 0.3447]^T$$
$$W_{Kenth} = [0.0518 \quad 0.1103 \quad 0.0984 \quad 0.1139 \quad 0.1250 \quad 0.1488 \quad 0.1974 \quad 0.1545]^T$$
$$W_{Sonic} = [0.2158 \quad 0.1079 \quad 0.0723 \quad 0.1168 \quad 0.1555 \quad 0.0940 \quad 0.1188 \quad 0.1188]^T$$

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	Organisational Environmental & Laws	Technology & Manufacturing Ability	Financial Operation ability	Reputation	Management & Business Professionalism	Effective Cost	On Time Delivery	Quality	SQ|Wij|	|Wij|
W1=(Newton)	0.030700	0.045800	0.058800	0.085500	0.109400	0.153700	0.190100	0.326100		
W2=(LPg)	0.032300	0.049900	0.054700	0.070700	0.107800	0.134600	0.205200	0.344700		
W3=(Kenth)	0.051800	0.110300	0.098400	0.113900	0.125000	0.148800	0.197400	0.154500		
W4=(Sonic)	0.215800	0.107900	0.072300	0.116800	0.155500	0.094000	0.118800	0.118800		
|W1|	0.000942	0.002098	0.003457	0.007310	0.011968	0.023624	0.036138	0.106341	0.1919	0.4380
|W2|	0.001043	0.002490	0.002992	0.004998	0.011621	0.018117	0.042107	0.118818	0.202187	0.449652
|W3|	0.002683	0.012166	0.009683	0.012973	0.015625	0.022141	0.038967	0.023870	0.1381	0.3716
|W4|	0.046570	0.011642	0.005227	0.013642	0.024180	0.008836	0.014113	0.014113	0.1383	0.3719
									sum	
W1.W2	0.000992	0.002285	0.003216	0.006045	0.011793	0.020688	0.039009	0.112407	0.1964	
W1.W3	0.001590	0.005052	0.005786	0.009738	0.013675	0.022871	0.037526	0.050382	0.1466	
W1.W4	0.006625	0.004942	0.004251	0.009986	0.017012	0.014448	0.022584	0.038741	0.1186	
W2.W3	0.001673	0.005504	0.005382	0.008053	0.013475	0.020028	0.040506	0.053256	0.1479	
W2.W4	0.006970	0.005384	0.003955	0.008258	0.016763	0.012652	0.024378	0.040950	0.1193	
W3.W4	0.011178	0.011901	0.007114	0.013304	0.019438	0.013987	0.023451	0.018355	0.1187	
Cos(WIJ)	=(WI.WJ) /|WI|*|WJ|									
cos(W12)	**0.997305**									
cos(W13)	**0.900678**									
cos(W14)	**0.727912**									
cos(W23)	**0.884948**									
cos(W24)	**0.713432**									
cos(W34)	**0.859000**									

Phase Angle Difference	W1	W2	W3	W4
W1	***0.0000***	4.21	25.75	43.29
W2	4.21	***0.0000***	27.76	44.49
W3	25.75	27.76	***0.0000***	30.80
W4	43.29	44.49	30.80	***0.0000***

Euclidian norm	Organisational Environmental & Laws	Technology & Manufacturing Ability	Financial Operation ability	Reputation	Management & Business Professionalism	Effective Cost	On Time Delivery	Quality	SQ|Wij|	|Wij|
W1=(Newton)	0.030700	0.045800	0.058800	0.085500	0.109400	0.153700	0.190100	0.326100		
W2=(LPg)	0.032300	0.049900	0.054700	0.070700	0.107800	0.134600	0.205200	0.344700		
W3=(Kenth)	0.051800	0.110300	0.098400	0.113900	0.125000	0.148800	0.197400	0.154500		
W4=(Sonic)	0.215800	0.107900	0.072300	0.116800	0.155500	0.094000	0.118800	0.118800		
W12: W1-W2	-0.001600	-0.004100	0.004100	0.014800	0.001600	0.019100	-0.015100	-0.018600		
|W1-W2|	0.000003	0.000017	0.000017	0.000219	0.000003	0.000365	0.000228	0.000346	0.0012	**0.0346**
W13	-0.021100	-0.064500	-0.039600	-0.028400	-0.015600	0.004900	-0.007300	0.171600		
	0.000445	0.004160	0.001568	0.000807	0.000243	0.000024	0.000053	0.029447	0.0367	**0.1917**
W14	-0.185100	-0.062100	-0.013500	-0.031300	-0.046100	0.059700	0.071300	0.207300		
	0.034262	0.003856	0.000182	0.000980	0.002125	0.003564	0.005084	0.042973	0.0930	**0.3050**
W23	-0.019500	-0.060400	-0.043700	-0.043200	-0.017200	-0.014200	0.007800	0.190200		
	0.000380	0.003648	0.001910	0.001866	0.000296	0.000202	0.000061	0.036176	0.0445	**0.2110**
W24	-0.183500	-0.058000	-0.017600	-0.046100	-0.047700	0.040600	0.086400	0.225900		
	0.033672	0.003364	0.000310	0.002125	0.002275	0.001648	0.007465	0.051031	0.1019	**0.3192**
W34	-0.164000	0.002400	0.026100	-0.002900	-0.030500	0.054800	0.078600	0.035700		
	0.026896	0.000006	0.000681	0.000008	0.000930	0.003003	0.006178	0.001274	0.0390	**0.1974**

Euclidian norm	W1	W2	W3	W4
W1	***0.0000***	0.0346	0.1917	0.3050
W2	0.0346	***0.0000***	0.2110	0.3192
W3	0.1917	0.2110	***0.0000***	0.1974
W4	0.3050	0.3192	0.1974	***0.0000***

Priority Weight Evaluation	Organisational Environmental & Laws	Technology & Manufacturing Ability	Financial Operation ability	Reputation	Management & Business Professionalism	Effective Cost	On Time Delivery	Quality
W1=(Newton)	0.030700	0.045800	0.058800	0.085500	0.109400	0.153700	0.190100	0.326100
W2=(LPg)	0.032300	0.049900	0.054700	0.070700	0.107800	0.134600	0.205200	0.344700
W3=(Kenth)	0.051800	0.110300	0.098400	0.113900	0.125000	0.148800	0.197400	0.154500
W4=(Sonic)	0.215800	0.107900	0.072300	0.116800	0.155500	0.094000	0.118800	0.118800
W(Criteria Priority Weight)	**0.056020**	**0.072590**	**0.070800**	**0.092710**	**0.118210**	**0.140530**	**0.189690**	**0.259470**

APPENDIX F: CRITERIA SCORING TABLE

Criteria	Priority Weight	Sub-criteria	Abbreviation	Priority Weight	Outsourcee SUPD = S1	Outsourcee S2	Outsourcee S3	Outsourcee S4
Organisational & Environmental Laws **OEL**	**0.0560**	Comply Business rules	**UBL**	0.5000	5	5	5	5
		Intellectual property protection Law	**UIPL**	0.5000	0	0	0	0
Technology & Manufacturing Ability **TMA**	**0.0726**	Hardware	**HdWr**	0.5889	10	5	5	5
		Personal Capability	**PlCp**	0.1593	10	7	5	5
		Process Capability	**PrCp**	0.2519	7	5	10	7
Financial Operation Ability **FA**	**0.0708**	Financial Stability (Not subject to Bankruptcy)	**NBcy**	0.5000	10	5	5	0
		Time (Duration) in business	**TIB**	0.5000	5	7	5	5
Reputation **Re**	**0.0927**	Responsiveness to change	**ResCh**	0.0500	0	0	0	0
		Flexibility to adjust changes	**FlCh**	0.1672	0	0	0	0
		Link with a number of low tier suppliers	**NoLT**	0.0812	0	0	0	0
		Linked suppliers comply quality standards	**QSLT**	0.0969	0	0	0	0
		Secure communication system	**SCom**	0.1672	0	0	0	0
		Information declaration about linked suppliers	**IDLT**	0.1672	0	0	0	0
		Linked suppliers participate in improvements	**IPLT**	0.1224	0	0	0	0
		Good relationships with linked suppliers	**GRLT**	0.1460	0	0	0	0
Management & Business Professionalism **MBP**	**0.1182**	Understands the business requirements of the customer	**UBR**	0.7500	10	10	7	7
		Trained staff to develop good customer relationship	**TSCR**	0.2500	5	5	0	5
Effective Cost **CE**	**0.1405**	Competitive Cost	**CmC**	0.5889	7	10	5	5
		Sustainable Cost	**SC**	0.1593	5	5	0	0
		Consistent Cost	**CCn**	0.2519	0	0	0	0
On Time Delivery **OTD**	**0.1897**	Delivery lead time	**DLT**	0.2973	5	10	5	7
		Delivery Consistency	**DC**	0.5390	7	7	5	5
		Delivery Documentation	**DD**	0.1638	10	5	0	0
Quality **Qu**	**0.2595**	Product Standard	**PS**	0.4778	10	7	5	0
		Design Standard	**DS**	0.3500	10	7	5	0
		Material Standard	**MS**	0.1722	5	5	5	5