Master Thesis Report

A predictive sourcing model for multi Export Credit Agency financed large industrial projects

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PREFACE & ACKNOWLEDGEMENTS

This thesis presents the results of my master thesis project for the MSc program 'Management of Technology (MoT)' at Delft University of Technology. The past five months I performed my thesis project at CB&I, through an internship.

CB&I designs, engineers and constructs some of the world's largest energy infrastructure projects, providing EPC solutions and proven technologies. Within this thesis a clear contribution has been made to preliminary cost estimation methodology for large industrial projects, which is focused mainly on achieving cost reductions. In order to achieve this, a multi-disciplinary approach was a necessity. This involves strategic sourcing, descriptive statistics on sourcing, cost comparisons among countries, the role of export credit agencies in trade finance, linear optimization, and Monte Carlo simulations. Minor academic contributions have been made in all these disciplines, but combining all of this disciplines is a major contribution. Moreover its practical applicability has already proven its value, as CB&I is using the new estimation methodology to visualize credible cost estimations for the client. It is planned to use this methodology in future projects.

First of all I would like to thank the members of my graduation committee affiliated to the TU Delft their critical reflections and useful contributions to the thesis:

- Prof. dr. ir. W.A.H (Wil) Thissen
- D. Phil. (Res.) S.W. (Scott) Cunningham
- Dr. S.T.H. (Servaas) Storm.

Without Scott Cunningham, which is my first supervisor, this thesis would not have been possible. To start with, the formation of the graduation committee was a large hurdle, due to its multidisciplinary nature and recent changes in the graduation committee rules. Scott has made considerable effort in advising on a suitable committee, and requesting for an exemption for not complying fully with the graduation committee regulations. I addition Scott helped me enormously in selecting appropriate statistical methods, their methodologies, and interpreting the results, but always stimulated me to use own inputs to finalize the thesis in a way I thought was most suitable. Whatever the statistical issue that was at stake, Scott could immediately respond with a theory, a method, and its alternatives. His door was always open, helping me with proceeding on the research when I was once again stuck in the maze of a multidisciplinary thesis involving statistical methods never taught to me on the University.

This thesis project could not have been conducted without the pleasant internship at CB&I. I was surrounded by a large number of experts in the field of business development, procurement, project controls, estimation, and engineering, all were willing to clarify and deliver inputs when needed. In addition, responsibilities were entrusted to me, emphasizing the feeling that I was not just an intern, but a valued member of the project team. I would like to thank my external supervisor Dorus Everwijn for providing me with an internship in the interface between engineering and business, which perfectly connected my background in chemical engineering and management of technology. A special thanks to Eric de Jong, who helped me numerous times in collecting the necessary data for cost estimation.

Thanks to all family and friends for the love and support, without you this thesis would be impossible.

Paul Jansen - Delft, August 2013

EXECUTIVE SUMMARY

CB&I is experiencing an issue in a new project to be executed in Russia, named NKNK. Despite the rich experience CB&I has with projects, there is a continuous struggle with the sourcing process in projects which it involves financing by multiple export credit agencies. The issue at stake is, CB&I does not know beforehand in which countries it is most likely to source its equipment to achieve to lowest possible sourcing costs. However, budgets available in countries will be set in an inception phase of a project. A preliminary estimation method is needed to determine the amount of budget needed in multiple countries, in order to increase the probability of minimizing total sourcing costs. In order to accomplish this, a new cost estimation methodology is needed. This combines strategic sourcing theory, descriptive statistics on suppliers, cost differentials among countries of manufacturing, macroeconomic theory, the role of export credit agencies in trade finance, conventional cost estimation methods, linear optimization, and Monte Carlo simulations.

The importance of strategic sourcing is underpinned in this thesis. Theoretical optimal sourcing strategies are suggested on the basis of the level of perceived competition. The perceived level of competition within different industries is acquired through questionnaires with industry experts. The suggested sourcing strategies are tested on their practical applicability in large industrial projects. It turns out that there are serious limitations in applying multiple sourcing strategies, due to the nature of the highly customized equipment needed in these projects. Predominantly, single sourcing strategies are used, in which a number of suppliers is inquired for a bid. It is shown, through a linear regression analysis, there is a significant positive correlation between the perceived level of competition and the number of suppliers inquired for a bid.

Descriptive statistics on suppliers involve per equipment type (more formally known as purchase order category), the number of suppliers selected and their most likely country of manufacturing. It is discussed that there are multiple restrictions in selecting potential suppliers for a project. Firstly, suppliers can only be selected and inquired for a bid, if they are stated in an 'Approved Vendor List'. Secondly, ECA involved financing limits the budget available in each country to a certain extent. Therefore, selecting suppliers in a country where probably no budget is available, is a waste of effort. Thirdly, the increasing administrative burden in selecting larger numbers of suppliers poses limitations. Through a comparison on descriptive statistics on suppliers in two very similar projects, but with different project contexts, the effects of these limitations are determined.

It is hypothesized there are sourcing cost differences among countries for particular purchase order categories. Through a literature review, macroeconomic factors that could explain these cost differentials are determined. These are categorized in economic-, infrastructural-, labor, supply based, and political factors. For each macroeconomic category indicators are selected to represent these. A total of twelve indicators per country are reduced to two factor scores per country, through a dimension reduction technique (principal component analysis). Based on quotations submitted by suppliers for a completed project in the near past, significant cost differentials among countries are determined using categorical variables in a linear regression. A statistical refinement has been done to place countries in a cost category. Factor scores per country and descriptive statistics on suppliers are used to substantiate these cost rankings. Combining cost differentials, macroeconomic indicators, and descriptive statistics proved to be a valuable tool to determine in which country one is most likely to receive the least expensive quotations.

The role of export credit agencies (ECAs) in project finance is explored through a literature review. ECAs cover political and commercial risks for exporters and credit providing entities. ECAs are heterogeneous and there is no definitive model for ECAs. For terms associated with project finance (medium- to long-term), the most widely used mechanism by ECAs is buyer credit. ECAs are involved by issuing insurance, for defaults, directly to the exporter's bank. ECAs are also involved in buyer credit by offering a precompletion risk facility. A recourse agreement is included, meaning defaults caused by the exporter can be reclaimed from the exporter and disbursed to the lending bank. To quantitatively compare differences in terms and conditions of ECAs, a new methodology is developed in this thesis. This methodology involves a discounted 'Interest Rate Coefficient', which incorporates ECA premiums rolled over into the loan in the financing period, and terms and conditions involved in the repayment period. Through a questionnaire terms and conditions applicable to the NKNK project are acquired, which are mainly budgetary constraints, insurance premiums, and interest rates. Combining the results of the questionnaire and the interest rate coefficient, necessary inputs are obtained for linear optimization and Monte Carlo simulations.

The basis of the newly developed preliminary sourcing cost estimation methodology is a 'sourcing allocation table', which can be used as a direct input in a linear optimization model developed in line with this thesis. The methodology starts with listing all purchase orders for a project in the sourcing allocation table. Next, it is evaluated which data is readily available, with respect to suppliers, supplier countries, quotation values, and purchase order value estimates. Data which is not readily available on suppliers and supplier countries are estimated per purchase order category, based on the descriptive statistics on number of potential suppliers and their distribution among countries. For purchase orders of which no quotations or estimates are available, conventional estimation techniques are used. The order of magnitude method is used on a reference project, which is indexed to accommodate the inflationary impact of time. Dummy quotations are generated to fill in the missing data on suppliers, their countries, and quotation values. These dummy quotations take significant cost differentials among countries per purchase order category into account. In these quotations, values are randomly generated according to the average spread of quotation values, using a uniform distribution. Trade finance estimates are also included in the sourcing allocation table. Now the sourcing allocation tables contains, based on live data and dummy quotations, for each purchase order a number of suppliers, their country in manufacturing, and quotation values. As there are numerous randomly generated parameters, there is no definitive optimized value. Rather there is a range of possible outcomes, determined by doing a Monte Carlo simulation with the linear optimization model. The output of these simulations are, a probability distribution of the total optimized value, a probability distribution of the expenditures within each country, and an average distribution of ECA budgetary flows towards sourcing countries.

The new methodology for preliminary estimation of sourcing costs is seen by CB&I as a valuable tool to determine in an early phase of the project where budgets are most likely needed. This allows to set ECA budgets properly, to increase the probability of minimizing sourcing costs. The first results are already presented to the client, which was impressed with the result. It gives a clear graphical representation of the estimated total costs, budgets needed in which countries, and where the budgets are spent. Evenly important, it shows the uncertainty in all these estimates, through probability distribution. In addition, this tool allows easy identification of the cost impact of different scenarios, such as exploring the cost effect of excluding budget from a certain ECA country.

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CHAPTER 1 INTRODUCTION

In this Chapter the master thesis is introduced, through a research proposal. In Section 1.1 the research background is described, in which general information about the company (CB&I) and the project under study is given. Section 1.2 contains the research context, which states the problem related to this research. The research objective is stated in Section 1.3, which should solve the problem stated in the research context. A literature review to explore theory related to this thesis is done in Section 1.4. Based on this literature review, research question are stated in Section 1.5. The research methodology used in this thesis, is described in Section 1.6. A conceptual model is proposed in Section 1.7. In section 1.8 the multidisciplinary structure of this thesis is clarified. The scientific and managerial relevance are discussed in Section 1.9.

1.1 RESEARCH BACKGROUND

This thesis is conducted at the Chicago Bridge and Iron Company, or CB&I, through an Internship. The name CB&I origins from a merger in the late 19th century, but is nowadays not involved in the construction of bridges nor iron works. Its core business activities are: Engineering, Procurement, and Construction (EPC) of large energy related projects. CB&I operates in over 80 countries and has, due to the recent acquisition of The Shaw Group, approximately 50,000 employees. The business sectors of CB&I, which are involved with EPC, can roughly be divided into 3 parts.

1. Lummus Technology, which was acquired in 2007, provides licensed proprietary technologies, specialty equipment, and catalysts that are essential in the conversion of crude oil into end products (e.g. diesel, gasoline).
2. Project engineering and construction, which provides engineering, procurement, fabrication, and construction of up- and down-stream process facilities in the energy industry.
3. Steel Plate Structures, which is the world's largest and most experienced tank construction company. The activities cover designing, fabricating, and constructing storage tanks, containment vessels, and their associated systems.

CB&I's strategy focusses on a select group of growth industries: Liquid Natural Gas (LNG), Gas Processing, Refining, Petrochemicals, Oil Sands, Offshore, and Nuclear Power.

Recently, CB&I has been contracted for the EPC of a plant for the petrochemical company NizhnekamskNeftekhim Inc., more formally known as NKNK. It is located east of Moscow, in the city of Nizhnekamsk, in the Tatarstan Republic of Russia. Tatarstan produces 32 million tons of crude oil per year and has estimated reserves of more than 1 billion tons.[1] NKNK is one of the largest producers of petrochemicals and has the largest petrochemical complex of Eastern Europe. It had (in 2010) a revenue of 3.1 billion USD, a profit of 222 million USD, and employed over 17,000 people. The petrochemical plant to be constructed, is an ethylene cracking unit. This plant will have a production capacity of 1 million tons annually (MTA) of ethylene, 0.45 MTA of propylene, and 0.32 MTA of benzene. The feedstock for the production process will consist of liquid naphtha, butane, and propane.

[1] Economy: The Republic of Dagestan, Retrieved from: http://www.tatar.ru/index.php?DNSID=c0ab50580ba8d76a95c91a570958a02a&node_id=792

The scope of the work delivered by CB&I, is shown in Figure 1. The project is referred to as the 'NKNK project'.

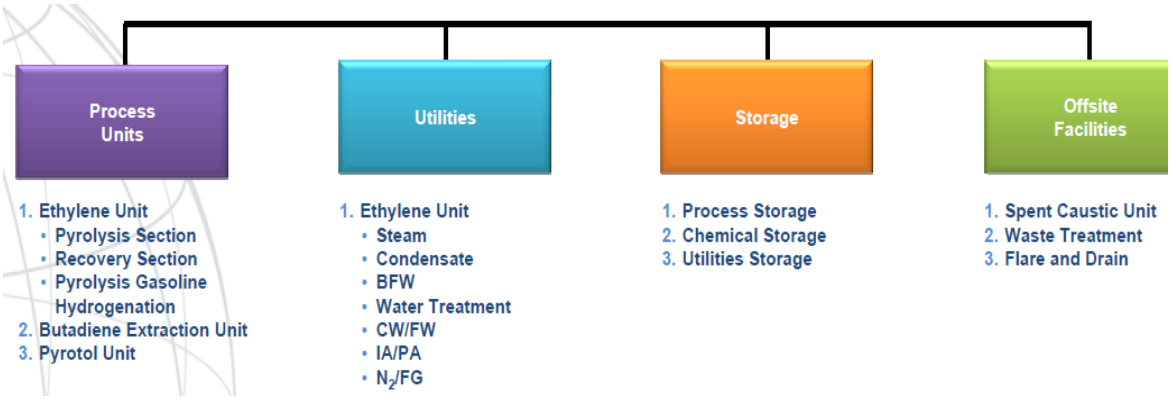

Figure 1: Scope of Work for the NKNK project: Ethylene plant

Source: CB&I

CB&I will also assist in financing. NKNK needs credit for the execution of the project. Therefore a cost estimate is done by CB&I, to determine the amount of credit needed to purchase all necessary equipment for the plant. A straightforward way to do this is to determine the value of each piece of equipment, by requesting quotations from suppliers, and add them all up. This approach is a time and labor intensive activity, where time is of crucial importance to meet project objectives. CB&I is looking for alternatives to make accurate cost estimations on the basis of experience with previous projects, the number of purchase orders, and only a few quotations for the project in execution. When the cost estimation is finished and approved, CB&I can start the sourcing process. Cost reductions can be achieved by strategic sourcing, but the whole procurement process must be carefully examined to make optimized choices on price differentials between suppliers, and differences in terms & conditions among credit providing entities. To add to the complexity, procurement can also be constrained by the production capacities of preferred suppliers.

1.2 RESEARCH CONTEXT

Large industrial projects often require huge amounts of capital. Project owners can be dependent on external financing for a project. For large industrial projects, a common mechanism to finance import of goods & services, involves Export Credit Agencies (ECAs). ECAs are predominantly quasi-governmental institutions, which can support financing abroad. This is done through direct credits, credit insurance, and guarantees. These are usually given with a minimum domestic content requirement, of the total contract value. The prime objective of ECAs is to stimulate exports by taking risks away from investors and exporters. Some projects require, due to their size, financing from multiple ECAs located in different countries. This delocalization can result in problematic allocation of funds, as there could be surplus of funds in one country and a deficit in another. Consequently, large industrial projects can be forced to purchase goods a higher price than would otherwise be the case. CB&I desires a model and a tool for the alignment of ECA conditions and the sourcing plan.

1.3 RESEARCH OBJECTIVE

The research objective of this thesis is formulated as follows:

To offer the Head of the Procurement Department recommendations concerning how to improve the alignment of ECA involved financing and sourcing plans, by developing a predictive model on sourcing costs for large industrial projects.

1.4 THEORY

In order to achieve the research objective, a literature review is done. This determines which knowledge is already in place, and where knowledge gaps are. This research proposal consists of 2 theoretical perspectives, the cost of sourcing (Sub-Section 1.4.1) and predictive modeling of sourcing (Sub-Section 1.4.2):

1) Procurement is not as straightforward as one might expect. It is often a complex process involving, multiple countries, changing market conditions, and asymmetric information. Paragraph 1.4.1.1 shows that theory on strategic sourcing is of vital importance, in determining an optimal sourcing strategy. In sub-Sub-Section 1.4.1.2, it is described that sourcing of large industrial projects frequently involves Export credit. The role of Export Credit Agencies, and their share in total sourcing costs, needs a careful theoretical examination. Paragraph 1.4.1.3 focusses on the macroeconomic factors affecting sourcing costs among countries.
2) In projects one can wait for all suppliers to present their quotations for requested goods & services and thereby estimate the sourcing costs of a project. This is however time consuming, where excess time is often not abundant in projects. Theory is needed to develop a preliminary estimation method, to accurately estimate sourcing costs.

In the following Sub-Sections these theories are discussed in the project context.

1.4.1 THEORY ON THE COST OF SOURCING

In this Sub-Section the importance of strategic sourcing, the involvement of export credit agencies, and the macroeconomic criteria that affect sourcing costs among countries are discussed.

1.4.1.1 STRATEGIC SOURCING

Strategic sourcing is an institutional procurement activity to improve purchasing activities of a company. It involves an important decision: single or multi-sourcing. In single sourcing a buyer attempts to get all specific equipment it needs, from a single seller. If there is no information asymmetry, suppliers are assumed to have strictly convex costs. In the case of only a single buyer this buyer will be better off applying a single sourcing strategy. The reasoning behind the use of a single sourcing strategy is as follows: other potential sources (suppliers) end up producing nothing and therefore suppliers engage in an all-out competition to win the tender. This is known as the Bertrand model. However this could, result in stock-out, in which a single supplier could not meet demand. This can lead to crisis situations in projects. Applying a multiple sourcing strategy reduces this risk. Multiple sourcing strategies are long-term oriented, in contrast to single sourcing strategies, which are more short-term oriented. Single sourcing strategies can stimulate the formation of monopolies, and thereby eliminating competition on the long-term. When there are multiple buyers in the market,

there is a 3rd reason for a multiple sourcing strategy. Inderst (2008) has shown with a game theory approach: if two symmetric buyers are facing 2 symmetric suppliers, purchasing costs are minimized when each of the buyers spreads his procurement evenly over suppliers. In that specific case, a single sourcing strategy would be the worst strategy possible for buyers.

The strategic choice between single or multiple sourcing is mainly dependent the level of competition among buyers and suppliers in a specific industry. The level of competition is defined dependent on the following characteristics:

- The number of suppliers in the market, their capacities, and their scalability of production.
- The number of buyers in the market and their relative size (or market power).

These market characteristics need to be determined for project related industries, enabling the selection of appropriate sourcing strategies per industry.

1.4.1.2 THEORY ON THE ROLE OF EXPORT CREDIT AGENCIES IN SOURCING

Financing of international trade transactions is done by providing loans, insurance, guaranties, state subsidies, and other financial support in the form of derivatives. This is known as trade finance. Its main goal is to reduce risk and fill liquidity gaps, related to cross border delivery of goods & services. Most exporters and importers rely on financial institutions, for working capital and payments, as only a small portion of world trade is facilitated by other means (i.e. cash or barter). The global trade finance market is estimated to be about 15 trillion USD (Auboin, 2009). Key players in the field of trade finance are the following: commercial banks, private insurers, regional & multilateral banks, and Export Credit Agencies (ECAs). The latter is the main concern in this thesis.

ECAs have traditionally been a tool for governments to support domestic exports. These exports are important for a country's economy, as a balance of payments deficit (i.e. the imports of a country exceeds its exports) results in rising debt levels. Moreover, exports create employment. ECAs stimulate exports, in cases where commercial finance is not willing to cover exports, by acting as an insurer of last resort. Nowadays, ECAs are heterogeneous institutions in two different ways.

1) ECAs offer a mix of financial services to exporters.
2) ECAs have different operating and ownership structures (i.e. governmental, quasi-governmental, and commercial).

There is no definitive model for an ECA.

Nowadays, there are over 80 countries that have an ECA. The risks ECAs take away from investors and exporters, are ultimately borne by their governments. Therefore, ECAs are not allowed to compete directly with commercial institutions. Besides commercial risks (e.g. bankruptcy), political risks are often covered by ECAs, for loans that are frequently medium- (up to 5 years) to long-term (5-10 years). These terms are associated with large projects. ECAs are critical in these projects, because commercial lenders are frequently not willing to be involved in such risky, capital intensive, and long-term lending (at least not for an attractive premium). Since the economic crisis of 2008, where commercial lending markets were drying up, ECAs needed to fulfill an even more important role in trade finance. Several policy measures were taken, to prevent international trade markets from completely drying up. This is illustrated in Table 2. Following from this table: project related insurance increased a 5 fold in 2010,

compared to pre-crisis conditions. Despite a stagnating world economy, ECAs increased their money supply.

Table 1: Medium- to Long-Term Insurance and lending by Export Credit Agencies

(Source: Berne Union Statistics 2007-2011, http://www.berneunion.org)

	2007	2008	2009	2010	2011
Sovereigns	12,765	11,385	24,157	11,036	20,499
Other Public	27,180	23,608	30,345	26,336	33,707
Banks	8,790	6,799	6,091	5,717	7,092
Corporates	42,073	45,622	51,541	50,207	56,860
Projects	2,613	3,419	7,300	13,530	7,678
Unspecified	39,101	51,393	44,604	54,703	51,169
Lending	9,599	11,366	26,522	11,864	14,190
Total	142,121	153,592	190,560	173,393	191,195

(All figures given in million USD)

To prevent serious market distortions by ECAs, the Organization for Economic Cooperation and Development (OECD) members agreed upon an 'Arrangement on Guidelines for Officially Supported Export Credits'. Standardizing ECAs is the agreement's goal. However this does not ensure premiums, interest rates, and (repayment) terms are uniform for these ECAs. The agreement obligates ECAs to have floating interest rates, dependent on government bond yields of the domestic country. Risk premiums are to be determined by ECAs and are merely bonded to some guidelines. The practice is: there is room for negotiation in the financing of projects. The literature provides mainly qualitative data on ECAs, because it is focused on policy implications. The lack of publicly available data could be another reason for this knowledge gap.

To assess the cost of ECA involved trade finance, a quantitative comparison of terms & conditions (e.g. interest rates, terms, and budgetary constraints) must be made among ECAs.

1.4.1.3 MACROECONOMIC FACTORS

Macroeconomic factors can be defined as: factors pertinent to a broad economy at the regional or national level which affect a large population. Sourcing costs can be directly or indirectly subject to macroeconomic factors. They influence the prices charged, and quality of, goods & services delivered by suppliers. Macroeconomic factors affecting suppliers' costs of production need to be determined, to predict whether there are sourcing costs differences among countries. A macroeconomic analysis can reveal hidden costs and risks, which can significantly influence the sourcing process. Macroeconomic factors can be divided into 5 groups:

1. Economic factors (e.g. GDP growth, level of taxation, and currency risk).
2. Infrastructural factors (e.g. transportation time, transportation cost, physical infrastructure, and IT infrastructure).
3. Labor factors (e.g. labor turnover rate, labor cost, and educational level of worker).

4. Political factors (e.g. environmental regulations, corruption, export/import regulations, political stability, and enforcement of contracts).
5. Supply-based factors (e.g. maturity of industry, sourcing market attractiveness, capacity, and raw material cost).

Research has been done on the macroeconomic selection criteria firms use in their sourcing process (Global TCO, 2010). This research was mainly qualitatively and merely shows the importance of these criteria, in allocating suppliers for sourcing. That some criteria are valued more by importers than others, does not necessarily imply that these factors also have a higher impact on sourcing costs. Gutiérrez (1995) has shown how macroeconomic conditions, as well as other cost factors, have an impact on the production costs for suppliers in a multi sourcing environment. However, the macroeconomic costs were an assumed to be a known fixed parameter per country. What exactly, and to what extent, determine the macroeconomic cost factors is not stated. Literature is available on how sourcing costs are affected by the country chosen to source from (Swenson, 2005), but macroeconomics is not taken into account in that research. Sourcing in large industrial projects requires long term commitment in contracts and is therefore vulnerable for changing macroeconomic conditions over time.

More insight is needed on how macroeconomics factors, affect the cost of sourcing among countries.

1.4.2 THEORY ON A PREDICTIVE MODEL FOR SOURCING COSTS

To estimate the cost of sourcing in the early phases of a project, information in combination with a reliable cost estimating tool is needed. There are several methods for cost estimating in large industrial projects. A multiple regression technique has been suggested for cost estimations. To achieve acceptable estimating accuracy with this technique, parameters (e.g. macroeconomic factors) and their effects on sourcing costs, need to be understood. Also their magnitude must be determined. This technique is not accurate when describing multidimensional non-linear relationships (Tam & Fang 1999).

In large industrial projects, a more conventional method for cost estimation relies on reference data of previous similar projects. This method can take small differences into account, among similar plants. Industrial project costs can be estimated on the basis of the reference plant, although production capacities might differ. The method uses capacity factored estimates, which takes differences in capacity into account and adjusts these for possible scale advantages. This method can estimate the costs of the whole plant, as well as per piece of equipment (purchase order). This method is conventionally not used to predict in which country, and against what value, purchase orders are likely to be sourced. To estimate this accurately in an early phase has important implications for multi Export Credit Agency financed projects.

The sourcing costs of suppliers might differ among countries, due to differences in macroeconomic factors. Significant cost differences need to be taken into account, to estimate the values of quotations of suppliers, depending on their country of manufacturing. These country dependent estimates can be based on (capacity factored) estimates. A method needs be developed to estimate the number of potential suppliers that will be selected for a project per purchase order, and the countries they are located in. Therefore descriptive statistics is needed, to determine where suppliers are located for specific types of equipment. These suppliers and their location could be related to the project context.

Therefore the impact of project context on the selection of suppliers must be determined, to assess to what extent selected suppliers can be generalized for other similar projects. Financial constraints and financial costs of ECA countries need to be taken into account, to complement the method.

Purchase orders, quotations, cost estimates, dummy quotations, suppliers, countries of manufacturing, ECA country budget constraints, and financial costs need all to be combined into a single model, which can be used for mathematical optimization (i.e. calculate the lowest possible sourcing costs). By using random variables (based on estimates) in such a model, there will be a range of possible outcomes. Probability distributions can be derived for: estimated total sourcing costs, the ECA budgets needed for a project, and in which countries these budgets are needed (i.e. where the purchase orders are placed).

1.5 RESEARCH QUESTIONS

This Chapter consists of 5 central research questions. These are derived out of the literature review and discussion of theory in Section 1.4. The central question are formulated in a way that they should contribute to the research objective. Each central question has several sub-questions. These are formulated in a way that they should give an answer to the corresponding central question. Definitive answers to each central question, according to this thesis' findings, are given in Section 7.1.

1.5.1 CENTRAL QUESTION 1

- What determines the amount of potential suppliers selected for a purchase order for large industrial projects?

1.5.1.1 SUB QUESTIONS OF CENTRAL QUESTION 1

- What are the sourcing strategies used in different competitive environments?
- What is the competition level among buyers and suppliers, for different purchase order categories, in the NKNK project?
- What sourcing strategies does theory suggest according to these competition levels and are these strategies applicable in practice?
- What is the correlation between perceived competition and the number of selected potential suppliers per purchase order in the NKNK project?

1.5.2 CENTRAL QUESTION 2

- What is the impact of project context on the selection of suppliers, with respect to supplier countries?

1.5.2.1 SUB QUESTIONS OF CENTRAL QUESTION 2

- Where are potential suppliers located, per purchase order category, in the NKNK project and in the reference project?
- What are the differences in project context between the NKNK and the reference project and how are these differences reflected?

1.5.3 CENTRAL QUESTION 3

- What are the cost differences among potential sourcing countries?

1.5.3.1 SUB QUESTIONS OF CENTRAL QUESTION 3

- What are the macroeconomic factors that result in sourcing cost differences among countries?
- Are there significant differences among countries with respect to sourcing costs?
- How can cost differences among countries can be explained by macroeconomic indicators?

1.5.4 CENTRAL QUESTION 4

- What is the impact of Export Credit Agency involved trade finance on total sourcing costs?

1.5.4.1 SUB QUESTIONS OF CENTRAL QUESTION 4

- What is an appropriate qualitative and quantitative model for Export Credit Agency involved trade finance?
- What are the terms & conditions of Export Credit Agencies involved in the NKNK project?

1.5.5 CENTRAL QUESTION 5

- How can predictions be made for the NKNK project on the optimized total costs of sourcing, ECA budgets needed, and the sourcing expenses in different countries?

1.5.5.1 SUB QUESTIONS OF CENTRAL QUESTION 5

- What data is available and missing for the NKNK project?
- What methods for cost estimation can be used for the NKNK project?
- What are the probability distributions of optimized total sourcing costs, ECA budgets needed, and the sourcing expenditures in different countries?

1.6 RESEARCH METHODOLOGY

In this Sub-Section the research methodology is discussed, which can be considered as roadmap to achieve the research objective. It is explained how data is collected, where it is collected from, and which type of data needs to be retrieved out of the data collection and analysis.

1.6.1 STRATEGIC PROCUREMENT IN LARGE INDUSTRIAL PROJECTS

The preliminary literature study brought interesting insights to the surface. The optimal sourcing strategy is dependent on the level of competition in the market, but often a single sourcing strategy is suggested to have an optimal outcome when purely considering costs. However, literature shows, when certain conditions hold, a multiple sourcing strategy should be more appropriate. Following from a more in depth literature study, an optimal sourcing strategy will be suggested for different purchase order categories in large industrial projects. Market characteristics on the level of competition, of these different purchase order categories, will be obtained through structured questionnaires. The units of analysis of this data collection method are procurement managers and (lead) engineers of CB&I. The data collected is on a Likert scale and is analyzed quantitatively. The market characteristics resulting from this analysis are used to determine optimal sourcing strategies suggested by theory. These are tested on their practical applicability by presenting the suggested strategies to experts in the field.

1.6.2 SUPPLIERS, SUPPLIER COUNTRIES, AND PROJECT CONTEXT

Data will be collected from procurement managers, for the NKNK project and the reference project, on the amount of the potential suppliers they have selected per purchase order category. It is determined where these potential suppliers are located per purchase order category. The selected suppliers (and supplier countries) are compared for the two projects, and related to the project context. In addition a correlation is determined between the outcome of the questionnaires (Sub-Section 1.6.1) and the number of selected suppliers. Through such a correlation the amount of potential suppliers, for each purchase order category, can be estimated on the basis of a questionnaire alone.

1.6.3 SOURCING COST DIFFERENCES AMONG COUNTRIES

The macroeconomic factors that affect sourcing costs among countries, will be explored through a literature review. Quotation data will be collected from the database of CB&I of the reference project. The data will consist of the following: purchase order name, supplier name, supplier country, and quotation value. Data will be pooled together using categorical variables. A linear regression analysis on this pooled data is done, using SPSS. Its outcome is analyzed using the Welch's t-Test and the Welch–Satterthwaite equation, to determine P-Values for each possible combination 2 countries. Using these P-Values, it is determined which countries are significantly different from one another (with respect to quotation value). The countries will be ranked from least expensive to most expensive using an experimental method in MS-Project. The cost rankings will be related to macroeconomic theory, and descriptive statistics on suppliers (i.e. what is produced by whom in which country).

1.6.4 EXPORT CREDIT AGENCY INVOLVED FINANCING

Through a literature review, models for different trade finance mechanisms are explored. The focus is on mechanisms for supplier credit and buyer credit, which are predominantly used in ECA involved trade finance. Financing terms & conditions of ECAs involved in the NKNK project can be predicted, to some extent, according to the OECD arrangement on officially supported export credit. Cost estimations (e.g. interest rates and insurance premiums) of ECA involved financing can only be obtained through experience and expert knowledge. Data collection, quantitative and qualitative, is done through a questionnaire with ING bank. The ING bank advices CB&I with respect to trade finance. Data is collected on the following ECA countries: Germany, Italy, Japan, the Netherlands and South-Korea. These countries will probably play a dominant role in the NKNK project, as CB&I is expected to source predominantly from these countries. Once financing costs are known of multiple ECA countries, a present value calculation is done on the financing and the repayment period. A comparison will be made between the initial value of the loan, and the total costs of the financing period plus the repayment period. This is shown in schematically Figure 2. The green line indicates the financing period, in which the

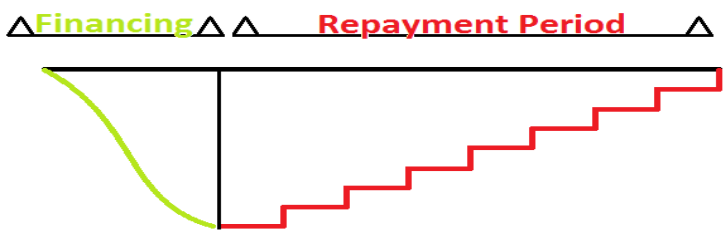

Figure 2: Schematic Representation of ECA involved financing costs.

(Green is financing period of projects, red is loan repayment)

equipment for the project is bought, with a loan that is rolled over every year until the start of the repayment period. In the repayment period (indicated in red), this rolled over loan is repaid in equal installments to the lender. ECAs are compared quantitatively on a concept developed in this thesis: an 'interest rate coefficient'. This coefficient be used as a financial parameter in a mathematical sourcing optimization model, which is ultimately used to simulate sourcing costs of the NKNK project. The optimization model is described mathematically in APPENDIX A and in wording in Sub-Section 6.5.1.

1.7 CONCEPTUAL MODEL

The conceptual model shown in this Section can be considered as a roadmap towards preliminary cost estimations of large industrial projects. In Figure 3 it shown how the different types of data, collected in this research, are combined. The data used as an input can be divided in 3 parts: trade finance data, reference project data, and data delivered by the procurement department. These 3 parts are used as an input in the sourcing optimization model, which calculates the lowest possible sourcing costs out of all the data. The input data used directly in the sourcing optimization model is indicated with dark blue in Figure 3. The use of dummy quotations, described in Sub-Section 1.7.2, allows the optimization model to have a range of possible outputs on: total sourcing costs, ECA budgets used, and sourcing costs within each country.

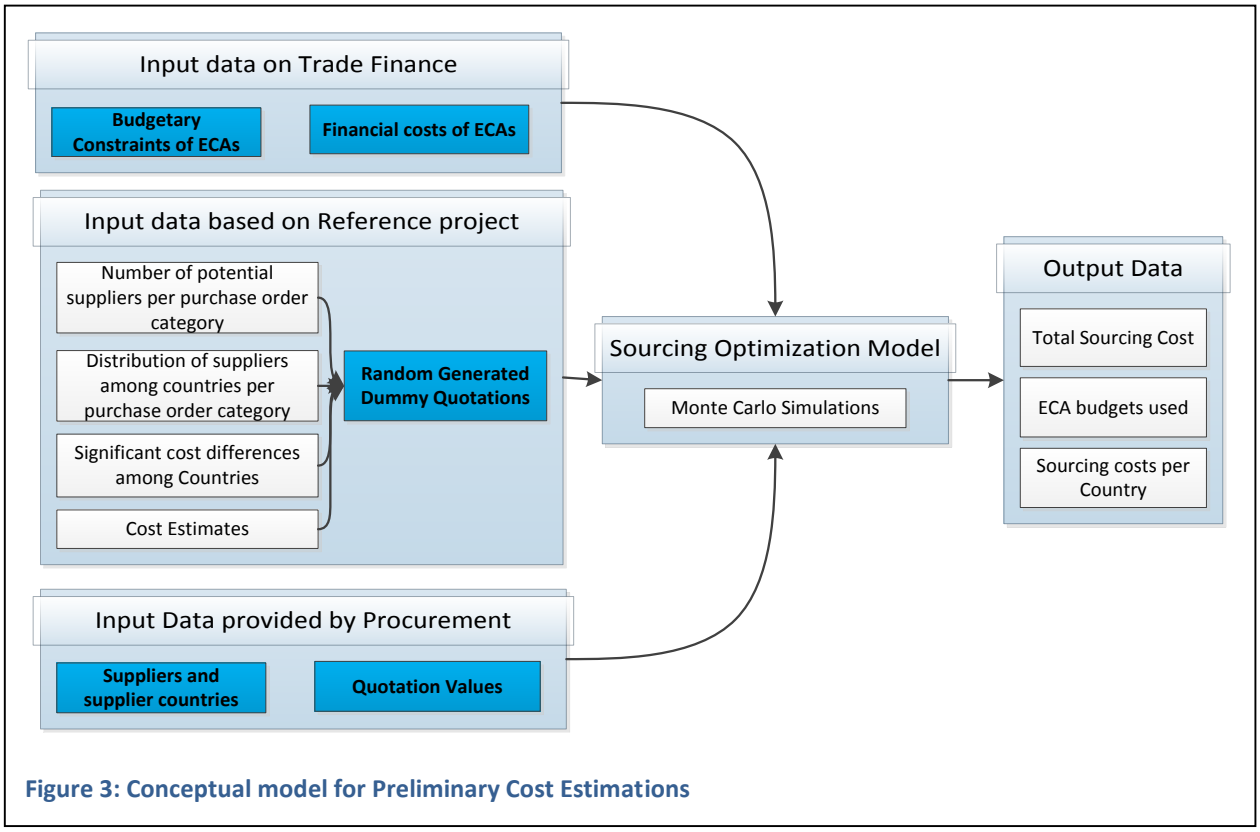

Figure 3: Conceptual model for Preliminary Cost Estimations

1.7.1 INPUT DATA ON TRADE FINANCE

The input data on trade finance will consist of the financing costs and budgetary constraints of 5 ECA countries: Germany, Italy, Japan, the Netherlands and South Korea.

- There are 3 financial constraints defined: firstly, a maximum amount of budget that can be used per ECA country; secondly, a minimum of that amount of that budget must be used for domestic content (i.e. must be spent within the ECA country); thirdly, a maximum amount of

that budget may be spent in the project country (Russia); fourthly a maximum amount of that budget may be spent in all other countries. All these budgetary constraints are used as an direct input in the sourcing optimization model.

- The financial costs will be determined per ECA country, based on the interest rate, the number of repayments per year, the start of the repayment period, the total term of the loan, and the discount rate. Based on these figures an interest rate coefficient will be calculated, on which each ECA country can be compared. This interest rate coefficient is used as a direct input in the sourcing optimization model.

1.7.2 INPUT DATA BASED ON REFERENCE PROJECT

Input data on purchase orders (suppliers, supplier countries, and quotation values), that is not readily available, is estimated.

- When a purchase order has an unknown number of potential suppliers, this number is estimated on the basis of descriptive statistics on the NKNK project, and the reference project.
- Unknown suppliers, or suppliers with unknown manufacturing countries, are estimated based on descriptive statistic on the NKNK project and the reference project.
- Significant cost differences among countries are determined on the basis of the reference project. Through quotations submitted by suppliers for this reference project, a cost ranking will be made from least expensive countries to most expensive ones.
- Cost estimates for purchase orders are obtained through 2 sources. The first source is the procurement/estimating department of CB&I. The second source is the reference project, on which indexed capacity factored estimate are done.

Dummy quotations are generated for purchase orders which have no live data available, based on the number of potential suppliers, supplier countries, and significant cost differences among countries. In these dummy quotations, supplier countries and values are randomly generated, corresponding to the statistics on supplier countries per purchase order category and cost differences among countries.

1.7.3 INPUT DATA PROVIDED BY PROCUREMENT

Input data that is readily available will not be estimated, but this live data is used as an input in the optimization model. Procurement can provide the following data:

- A list of potential suppliers, and their country of manufacturing, per purchase order.
- Quotation values submitted by the potential suppliers.

1.7.4 SOURCING OPTIMZATION MODEL

All data indicated in dark blue in Figure 3 is combined into a single excel sheet, which is imported in the sourcing optimization model. The model takes the financial constraints of the ECA countries, their financial costs, and all data on quotations for each purchase order into account. The model calculates the lowest possible outcome (optimization). The model is described in business wording in Sub-Section 6.5.1 and mathematically in APPENDIX A. Using random values for supplier countries and quotation values, the model simulates an output numerous times. All outputs of this ‘Monte Carlo Simulation’ are stored by the model.

1.7.5 OUTPUT DATA

The output data of the Monte Carlo simulations will be processed to probability distributions of the following:

- The optimized value of total sourcing cost: the sum of all costs, when 1 quotation is selected for each purchase order.
- The optimized amount of ECA budget used per ECA country. This includes, from each ECA country, where its budget is spent (domestic, Russia, other ECA countries, or rest of the world).
- The sourcing costs per country: The sum of all purchase orders sourced from a single country.

1.8 STRUCTURE OF THESIS

This thesis is multidisciplinary, therefore the structure of the thesis needs a thorough description to indicate how each Chapter is connected and relevant to this thesis. The 2nd Chapter contains sourcing strategies and practices, related to the competitive environment of sourcing for large industrial projects. In the 3rd Chapter, a thorough analysis is done on the number of suppliers and their country of manufacturing per purchase order. In the 4th Chapter, cost differences among sourcing countries are explored, and the nature of the cost differences are explained using macroeconomic indicators. In 5th Chapter, mechanisms for project finance are analyzed, and a method is developed to compare different countries in their financing costs. In Chapter 6 cost estimation methods are discussed, and a new cost estimation methodology is developed, which includes Monte Carlo simulations. This Section does not discuss general Chapters 1 (Introduction), 7 (Conclusions), and 8 (Reflection).

1.8.1 CHAPTER 2: SOURCING STRATEGY

The reasoning for the 2nd Chapter on sourcing strategies and practices is to explore the nature of the market in large industrial projects. This must reveal why certain suppliers are selected, and in what amounts. This Chapter firstly discusses sourcing strategies, dependent on the level of competition within the market. Next it is analyzed how the current level of competition is perceived by CB&I. Sourcing strategies are suggested on the basis of theory and the perceived competition. These sourcing strategies are discussed with experts of CB&I on their applicability in practice. This is done to develop a theoretical basis for of descriptive statistics in Chapter 3. One must understand the decisions made in order to determine whether they are arbitrary or not, and to which extend dependent on the project context. Thereby it can be determined whether it is justified to apply results from this analysis to other large industrial projects. Descriptive statistics in one project, without understanding the fundamentals on which they rely, could result in wrongful generalizations for other projects.

1.8.2 CHAPTER 3: DESCRIPTIVE STATISTICS ON SUPPLIERS

The 3rd Chapter provides mainly descriptive statistics on suppliers. The theoretical basis for this Chapter is discussed in Chapter 2, to examine whether the descriptive statistics can be applied on multiple similar projects. The descriptive statistics describes per purchase order category, how many potential suppliers are selected per purchase order, and in which country they are located. To complement the theoretical basis for potentially generalizing descriptive statistics on other projects, the project context and their descriptive statistics is compared among two projects very similar in scope. This provides a two way argument whether to generalize descriptive statistics for similar projects. In addition the

description statistics on suppliers will be used in Chapter 4 and Chapter 6. In Chapter 4 it will be used to explain sourcing cost differences among countries, and why countries have a competitive advantage in specific purchase order categories. In Chapter 6, descriptive statistics on suppliers is used in order to generate dummy quotations for suppliers, dependent on the purchase order category.

1.8.3 CHAPTER 4: SOURCING COST DIFFERENCES AMONG SUPPLIER COUNTRIES

In the 4th Chapter data on quotations of a reference project (ECC) is collected. Through a regression analysis, using categorical variables, it is determined which countries are cost wise significantly different from one another. The significant cost differences are used in Chapter 6, for to generate values for dummy quotations. In addition, through a literature review, macroeconomic factors are determined that could explain sourcing cost differences among countries. A set of 12 macroeconomic indicators are selected on the basis of these macroeconomic factors. Using principal component analysis, these 12 indicators per country are reduced to two factor scores per country. These factor scores, in combination with the descriptive statistics acquired in Chapter 3, are used to explain the fundamentals underlying sourcing cost differences among countries. Based on this analysis recommendations can be done, where one is most likely to receive attractive bids for a specific purchase order category.

1.8.4 CHAPTER 5: THE ROLE OF EXPORT CREDIT AGENCIES IN TRADE FINANCE

In Chapter 5, another discipline is added to the thesis. That Chapter focusses on Export Credit Agencies, the mechanisms under which they operate, how different terms and agreements of countries can be compared quantitatively, and its implications for the NKNK project. This is needed in the context of this thesis, because determining the sourcing costs of countries based only quotations does not reflect costs differences in trade finance among countries. Trade finance could significantly affect the cost of sourcing. E.g. sourcing a purchase order from a country that seemed to be the least expensive could possibly no longer be the least expensive option, when trade finance is taken into account. In addition, due to budgetary limitations, it could not always be possible to source a purchase order in a desired country. For these 2 reasons, the role of export credit agencies in trade finance needs to be taken into account, to represent a more accurate cost of sourcing. An interest rate coefficient is introduced to measure trade finance differences among countries, which is used in Chapter 6.

1.8.5 CHAPTER 6: PREDICTIVE SOURCING MODEL FOR SOURCING COSTS

In Chapter 6, inputs of previous Chapters are used to model sourcing costs. The Chapter is focused mainly to demonstrate the practical implications of the thesis, but surely adds academic content. The practical implications are demonstrated for the NKNK project, where first an evaluation is done on the available data. The missing data in the NKNK project is completed by conventional cost estimation methods, and the creation of dummy quotations based on the results of Chapters 3 & 4. Also the trade finance estimates determined for the NKNK project in Chapter 5 are used. In line with this thesis, a mathematical optimization is developed, to calculate the lowest costs out of a set of quotations, discussed in more depth in Section 1.7. With this model a prediction is done for the total sourcing costs of the NKNK project, where ranges of preliminary estimates are given for total sourcing costs, sourcing costs per country, and ECA country budgets used. The academic content this Chapter adds, is a newly

developed estimation method, which combines conventional methods, statistics, and linear optimization. The linear optimization model is truly academic content on itself.

1.9 RELEVANCE OF THIS RESEARCH

In this Sub-Section the relevance of this research is discussed in 2 perspectives, as this master thesis is relevant in a scientific (academic), as well as a managerial perspective.

1.9.1 SCIENTIFIC RELEVANCE

This master thesis will contribute to existing theories in the following ways.

- Theory on strategic procurement is complemented with results from a case study on strategic procurement in large industrial projects. The research aims at providing an optimal sourcing strategy in a multi actor environment, by using microeconomic theory.
- Through a comparison between two projects with a similar scope, the effect of project context is explored on the selection of potential suppliers for purchase orders, with respect to their country of manufacturing.
- Through a literature study, macroeconomic factors that could lead to sourcing cost differences among countries are explored. In addition it is determined whether there are significant sourcing cost differences among countries. Using macroeconomic indicators and descriptive statistics on suppliers, these sourcing cost differences are explained.
- It is examined if a Monte Carlo Simulation is a suitable method for predicting sourcing costs in large industrial projects. It is determined whether it is sufficient to have only minor data available from previous projects complemented with statistical data to make reasonable predictions on sourcing costs.
- Theory on Export Credit Agencies is complemented with their role on sourcing of large industrial projects. The research focusses on how the differences in terms & conditions of ECAs can be compared quantitatively.
- The research suggests a new method that combines live data, estimated reference data, statistics, randomly generated dummy quotations, and multi ECA financing constraints in order to make preliminary estimations on the total amount of budget that is needed for the sourcing activities of large industrial projects. Not only does it give an estimation on the total amount of budget needed, it also estimates in which countries budget is needed, and to what extent.

1.9.2 MANAGERIAL RELEVANCE

The practical aim of this research is to offer the head of the procurement department recommendations on reducing sourcing costs.

- Sourcing strategies are suggested, which should strengthen the position of CB&I in awarding purchase orders to suppliers, thereby reducing sourcing costs.
- Through statistical testing on a reference project, countries are ranked from least expensive to most expensive. This gives insights to managers from which countries they are most likely to receive the least expensive quotations, specified per purchase order category.
- A model and a tool is developed to compare ECA terms & conditions quantitatively. Through an interest rate coefficient the least expensive ECA countries can be selected.

- Cost estimations of sourcing can be done in early stages of the project, while only little live data is available, to provide valuable time for developing a sourcing financing plan. By the use of Monte Carlo simulations, estimated ranges of budgets are given according to an optimized sourcing plan. Relying on these estimates reduces the probability of budgetary mismatches.

CHAPTER 2 SOURCING STRATEGY

In this Chapter sourcing strategies are developed for different purchase order categories. The importance of strategic sourcing is underlined in Section 2.1. A distinction has been made between single and multiple sourcing methods in Section 2.2. Levels of competitions are defined, and sourcing strategies are suggested on the basis of these levels in Section 2.3. In Section 2.4, data collection is done on the market characteristics of different purchase order categories, for both the supply and demand side, through questionnaires with experts (procurement managers and engineers). This data is analyzed in Section 2.5 and the level of competition is defined for each category of purchase orders. The data analysis is summarized in Section 2.6. The market characteristics are applied to the different sourcing strategies discussed Ii Section 2.7, according to the competition levels. In Section 2.8 limitations in applying these suggested sourcing strategies are discussed. The conclusions are drawn in Section 2.9.

2.1 IMPORTANCE OF STRATEGIC SOURCING

In large industrial projects procurement, the act of buying or obtaining goods & services, is the indispensable link between engineering and construction. Together with these 2 processes, companies are able to execute construction projects from the drawing board to a fully operational deliverable. This is more formally known as EPC (Engineering, Procurement and Construction). The cost of materials represent a major part of the total EPC expenditure in projects (Jianhua & Yeo, 2000). Large industrial projects are characterized by a high tech environment, which includes custom made, specialized equipment and materials. Therefore, these projects have a high dependency on external companies: suppliers of goods & services. Being dependent on external companies for a process that determines to a large extent the total costs of projects, requires a strategic approach to manage risks, quality, and achieve cost reductions. Strategic sourcing is a maturing approach to tackle these issues. It can be defined as a procurement process that consists of planning, evaluating, implementing and controlling an organization' sourcing activities, to achieve its long-term goals (Carr & Smeltzer 1997).

Figure 4: Incentives for Strategic Sourcing

(Source: Aberdeen Group, 2011)

Strategic sourcing is seen as a powerful tool to increase business success. Besides the obvious cost savings that can be achieved by strategic sourcing, companies use it to identify new business opportunities and to develop meaningful supplier relationships. This valuable function contributes to corporate development and growth. Sourcing activities involve a wide variety of goods (e.g. raw materials, intermediate goods, and end products). Companies recognize the importance of strategic

sourcing by managing corporate spending with sourcing teams. According to a survey done by Aberdeen Group (2011), the most important reason of C-level managers to rely on sourcing teams is, not surprisingly, cost savings (Figure 4).

Cost reductions can be achieved by maintaining long-lasting relationships with suppliers through contract managing. This focusses on 3 main areas (OGC, 2002). The first area is service delivery management, which ensures products and services have the required level of performance, quality, and are delivered as is agreed upon. The second area is relationship management, which focusses on an open and constructive relationship between buyer and supplier. This allows resolving tensions and problem identification at an early stage. The third area is contract administration, which handles formal contract governance and documents changes to the contracts.

"All three areas must be managed successfully if the arrangement is to be a success." (OGC, 2002)

Contract management in sourcing is more an administrative and operational task, rather than being a real strategic sourcing objective. It is a traditional view on cost reductions by using a transaction theory approach (Virolainen, 1998). Large industrial projects require a more in depth strategic approach. It needs an approach to increase a company's buying power, without harming its relationship with suppliers. It should systematically address current market conditions to identify cost reduction opportunities. This starts with an analysis of the supply market, in which possible suppliers are identified, of which some general information is listed (e.g. location, reputation). Secondly, costs of supplier goods & services are determined on reference data. Note that this reference data is needed, as exact costs of goods & services are often not readily accessible in the preliminary phase of large industrial projects. The third stage is to select suitable vendors and suppliers on the basis of their projected costs, their locations, and their current market environment (e.g. capacities, political climate). When the number of suitable vendors and suppliers is known, a sourcing strategy can be developed in the fourth stage, on the basis of the highest probability to achieve the lowest sourcing costs within a specific industry. In the fifth stage this new sourcing strategy is implemented and its effectiveness is determined. This is a cyclical process in large industrial projects, because of the continuously changing environment, leveraged by financial crises, and environmental issues. The cyclical process in strategic sourcing is shown schematically in Figure 5.

Figure 5: Cyclical Process in Strategic Sourcing

2.2 SOURCING METHODS

There are broadly two sourcing methods, Single and Multiple Sourcing. Both have its advantages and disadvantages. The two methods are explained in this Section.

2.2.1 SINGLE SOURCING

Single sourcing is defined as a procurement activity of a buyer relying solely on a single supplier, for a particular good or service. A buyer could be forced into single sourcing, simply because there is only a single source. This single source is then called a monopolist. Using only a single source, when there are multiple sources available, is a strategic choice of a buyer. There could be several reasons for a firm to use a single souring strategy, according to a literature review done by Costantino & Pellegrino (2008):

- Single sourcing allows a long term relationship between buyers and suppliers, in which they cooperate, share benefits, and have high levels of mutual trust
- Single sourcing decreases the incentives for opportunistic behavior, i.e. taking selfish advantage of circumstances, without regarding the possible negative consequences for the partner.
- Long term commitment gives incentives to the supplier to invest in economies of scale and product development.
- Buyers are likely to demand similar products, increasing the price effects of learning by doing in the manufacturing process of the supplier.

There are some disadvantages of a single sourcing strategy:

- There is a great dependency between supplier and buyer.
- There is an increased vulnerability to the buyer of its supply.
- There is an increased risk of interruption in supply, especially for asset specific products.

2.2.2 MULTIPLE SOURCING

Multiple sourcing is defined as a procurement activity of a buyer, relying on multiple suppliers for a particular good or service. Obviously, this is only possible in the absence of a monopoly. Relying on multiple sourcing is a strategic choice of a buyer. According to a literature review done by Costantino & Pellegrino (2008), there could be several reasons for a firm to engage in a multiple sourcing strategy:

- Multiple sourcing allows switching to alternative sources in case of a supplier failing in supplying.
- Multiple sourcing reduces the probability of bottlenecks arising from an industry that tries to meet peak demands.
- Suppliers will engage in increased competition, which can lead to lower prices, higher quality, and increased innovation.
- Buyers have more flexibility to react to unexpected events, which could harm the capacity of suppliers.

There are some disadvantages of a multiple sourcing strategy:

- There could be reduced efforts by suppliers to match the requirements of buyers.

- Buyers face higher costs for the procurement process, as multiple sourcing increases total transaction costs.

Whether a buyer should rely on a single or multiple sourcing strategy, is dependent on the market characteristics, as shown in Section 2.3.

2.3 COMPETITION AMONG SUPPLIERS AND ITS STRATEGIC IMPORTANCE

In a market environment there is competition between suppliers, in order to maximize profit by obtaining a desired market share. The degree of competition seriously differs per industry and is dependent on the amount of buyers and suppliers within the market, and their relative size (Porter, 1986). Depending on the degree of competition, there is room for strategic behavior. Suppliers behave strategically to maximize profits. Buyers behave strategically in order to obtain desired products with the most favorable conditions possible. Firstly, different concentration levels are defined. Secondly, these different levels are elaborated upon. The expected strategic behavior of suppliers within each category is addressed. Thirdly, on the basis of expected behavior of suppliers, a strategic sourcing approach is suggested for buyers.

2.3.1 CONCENTRATION LEVELS

The power of suppliers, i.e. the influence they have on market price of their goods & services, is dependent on the concentration ratio (CR). This ratio is defined as the market share (s) of the set of largest suppliers within an industry (m). Common is, to measure the total market share of the four largest suppliers (m=4). This is shown mathematically in equation (1).

$$CR_m = s_1 + s_2 + s_3 + \cdots + s_m \quad (1)$$

This ratio indicates the market control of the largest firms, but there are no definitive concentration ratio's that can be used to determine the competitiveness within an industry. However, it is a good indication of the oligopolistic nature of an industry. Depending on this ratio, suppliers and buyers can determine their sourcing strategy. As a market is normally described in either perfectly competitive, oligopolistic or monopolistic it is straightforward to divide the concentration ratio, ranging from 0 to 100%, in 3 categories (Figure 6):

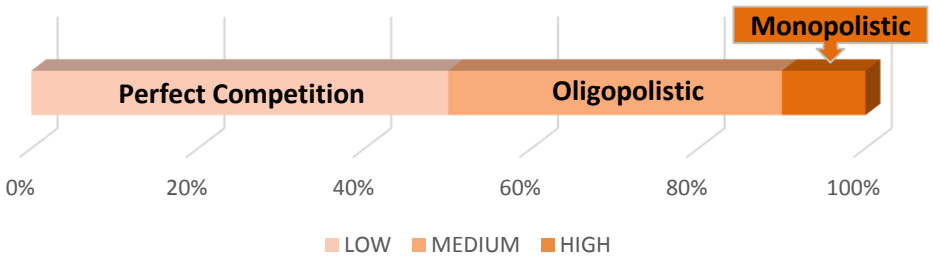

Figure 6 Concentration Ratios and their Market Characteristics

- Low CR (0-50%): This ranges from a perfectly competitive market to a market where there is a mild form oligopolistic competition and collusion.

- Medium CR (50-90%): This ranges from a mild form of oligopolistic competition, and collusion to a more heavy form of oligopolistic behavior which approaches monopolistic market characteristics.
- High CR (90%-100%): This ranges from a more heavy form of oligopolistic behavior, which approaches monopolistic market characteristics, to a full monopolistic market.

The market characteristics of the 3 ranges, in which the concentration ratio is categorized, are elaborated in the next 3 Sub-Sections. Note that the exact same reasoning can be done for buyers in the market. Oligopsony (medium CR) and monopsony (high CR) are the terms for imperfectly competitive buyers.

2.3.2 PERFECT COMPETITION AMONG SUPPLIERS

An industry is characterized by perfect competition, when there are sufficiently large numbers of buyers and suppliers within an industry. All suppliers and buyers in a perfectly competitive environment are assumed to be price takers, i.e. a buyer or a supplier has no power to influence market prices in a particular industry. There is a pricing mechanism in place which ensures that changes in price, in response to changes in demand and/or supply, have the effect of making demand equal to supply. This price is called the equilibrium price and is shown in Figure 7.

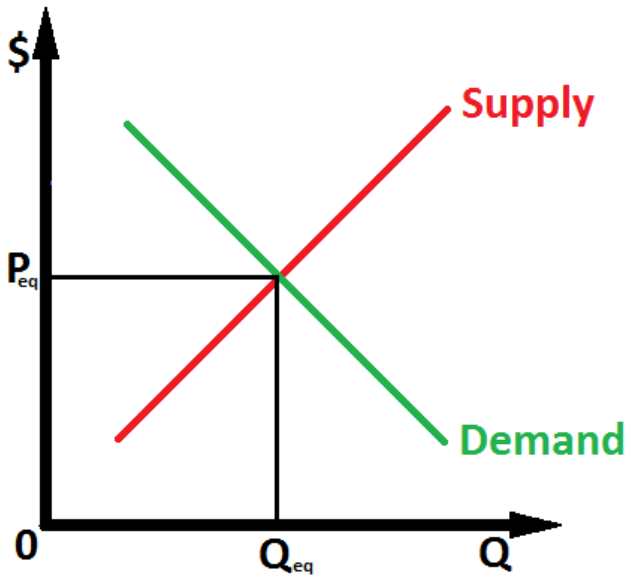

Figure 7: Demand and Supply curve, and the Equilibrium Point

For normal goods the supply curve is upward sloping, as production costs are likely to rise due to the law of diminishing returns. This law states that, as output expands marginal costs of production rise, because there is at least one factor of production (e.g. labor) that becomes limiting (e.g. over-hours are more expensive). Under perfect competition, the consequence is that a supplier will not have any influence on the market price of their goods & services (Boardman, 2006). Supply is determined by its marginal costs, meaning that a supplier will produce additional goods & services up to the the point where producing one additional unit of output will have higher costs than the price that would be received for that unit of output.

When there are supply shocks and/or demand shocks, the equilibrium price is subject to change. A sudden increase in demand, if it's sufficiently large, may cause the demand curve to shift to the right. This leads to a higher equilibrium price, as supply must meet demand in perfect competition. This is illustrated in Figure 8, where the initial equilibrium point (P_{eq1} , Q_{eq1}) is moved to a new equilibrium point (P_{eq2} , Q_{eq2}). This is of little strategic importance if it occurs through a general increase in demand in the market. When there is imperfect competition among buyers (i.e. buyers have market power), a

demand shift could occur if a single buyer in the market, that determines the demand in the industry to a large extend, increases its demand significantly. A specific industry that has a (group of) buyer(s), which is sufficiently large is called an oligopsony. Oligopsonists could be making their own purchases more expensive, when their demand increases. The supply side is demanding a higher price, as it is experiencing diseconomies of scale. To avoid suppliers raising their price, a buyer with market power must try to reduce its demand shock. This can be done with two multiple sourcing strategies.

Strategy 1: Divide the demand into demand tranches and spread these tranches over different time periods. The time periods must have sufficient intervals, to avoid suppliers reaching their capacity constraints.

Strategy 2: Divide the demand into demand tranches and spread these tranches over different geographical regions, which have little interaction, to avoid each region reaching its capacity constraints.

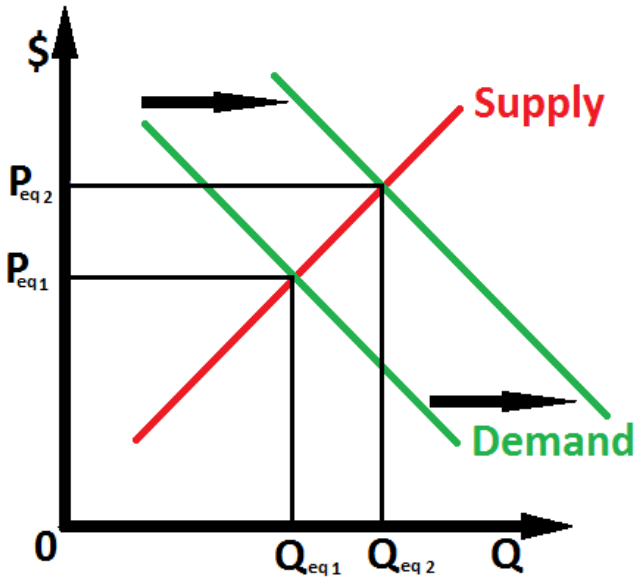

Figure 8: The effect of a Shift in the Demand Curve and its new Equilibrium Point

Both approaches have its limitations. It might not be possible to spread the demand over different time periods, e.g. if total demanded quantities are needed as soon as possible. A buyer might encounter higher transportation costs if demand is spread over geographical regions, thereby eliminating the cost reductions achieved by spreading.

Inderst (2008) has shown, using a game theory approach and assuming strictly convex costs for suppliers, spreading purchases evenly over suppliers will benefit oligopsonists, if all buyers demand approximately the same quantities. When there is a dominant firm, i.e. a buyer that represents a significant larger share of market demand than other buyers, this dominant firm would be better of using a single sourcing strategy. Obviously, this only holds until full capacity of that single source is reached. There is a crucial difference between the two. If there only is a single buyer, which commits credible to single sourcing, than all other suppliers end up producing nothing. Therefore, such a single sourcing strategy leads to an all-out competition between suppliers, until the price reaches marginal costs and no profits are left. This is known as the Nash equilibrium of the Bertrand model (McDowell, Thom, Pastine, Frank & Bernanke, 2012). When there are more buyers, and if one buyer commits to a single sourcing strategy, the other suppliers simply sell to the other buyer(s); not resulting in all-out competition. By spreading purchases equally over multiple suppliers, buyers (when of equally large size) obtain more attractive bids from suppliers (Inderst, 2008). This is consistent with strategies 1 & 2 suggested. Only when buyers have sufficient bargaining power one should consider the following strategy:

Strategy 3: Use a single sourcing strategy in order to create all-out competition between suppliers.

2.3.3 OLIGOPOLISTIC COMPETITION

When there is a small number of suppliers, which have a relatively large portion of the market share, this is called an oligopoly. In an oligopolistic characterized industry, suppliers can exert some power on pricing levels. This power is dependent on the concentration ratio of the suppliers within that industry. As with a monopoly, there are high barriers to the entry of new firms in an oligopolistic market. These barriers differ from industry to industry. Sometimes entrance to the market is relatively easy, in other cases it is virtually impossible. Because only a few firms represent a relatively large market share, its actions will affect other firms in the industry. Therefore, firms will have to take account of the others. They are interdependent, as each firm is affected by the actions of its rivals. A dominant supplier, i.e. a supplier significantly larger than all other suppliers, can be seen as price setter in the industry. There is no single generally accepted theory of an oligopoly, as firms may react differently and unpredictably. There are assumptions to be made on the most likely reaction firms, on actions of competitors. Broadly there are two strategies used by oligopolists: collude or compete.

In order to become a quasi-monopolist, suppliers can collude with other oligopolists to jointly achieve maximized industry profits. When this is done through a formal agreement, the firms form a cartel. This is seen by many governments as illegal, because it is against the public interest. Oligopolists can also achieve monopolist profits by tacit collusion, meaning that there is no formal agreement on pricing between firms. Firms tacitly agree on pricing to avoid price wars and aggressive advertising campaigns. Sloman & Jones (2011) have identified 8 factors that favor collusion:

- There are only very few firms, all well known to each other.
- The firms are open to each other about costs and production methods.
- They have similar production methods and average costs, and are likely to change prices at the same time and by the same amount.
- They produce similar products and can more easily reach agreements on price.
- There is a dominant firm.
- There are significant barriers to entry for new firms.
- The market is stable. Meaning that there are no large fluctuations in demand or production costs.
- There is no governmental policy in place acting against collusion.

When these factors favoring collusion are absent, it is more likely that oligopolists compete with one another. Suppliers compete with other oligopolists to gain market share, acquiring a larger portion of industry profits to themselves. Competing oligopolists have a disadvantage: aggregate profits of the industry will fall. This ambiguity does not necessarily mean the price is unstable, as firms face a kinked demand curve. There are two assumptions (Sloman & Jones, 2011) a supplier makes that result in the curve illustrated in Figure 9.

1. If a firm cuts its price the rivals will feel forced to follow the price cut, in order to prevent losing market share to competitors.
2. If a firm raises its price, the rivals will not follow. Rivals gain costumers by keeping their price at the same level.

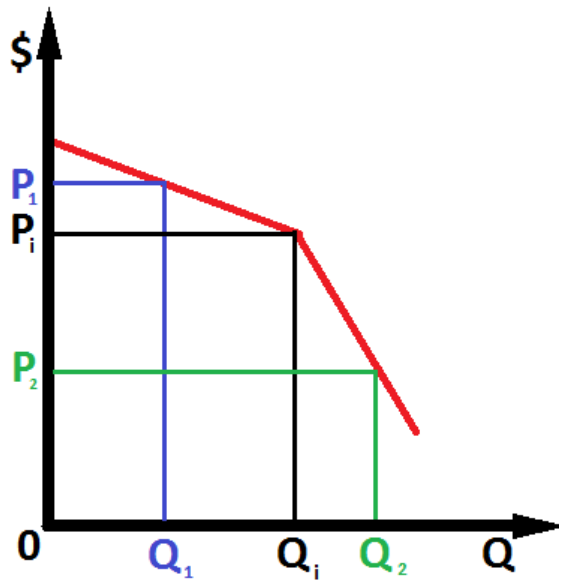

Figure 9: Kinked Demand Curve

(Price rise (P_i to P_1) is shown in blue; Price cut (P_i to P_2) is shown in green)

The kinked curve (Figure 9) indicates, if an individual supplier raises its price (from P_i to P_1), it will see a relatively large fall in its quantity sold (from Q_i tot Q_1). Therefore, a firm will be reluctant to raise its price. When a firm lowers its price (from P_i to P_2) it will see a relatively small rise in its quantity sold (from Q_i tot Q_2), as competitors will follow this price cut. There is nothing to gain, regarding profits, in either raising or lowering prices. Consequently oligopolists will be reluctant to change prices.

Competing solely on prices is not beneficial to the profitability of oligopolists, but there are other means by which they can compete. To gain market share oligopolists can use an extensive advertising campaign, which will be beneficial to consumers as it will decrease information asymmetry. The increase of unit price, due to its costs, is a disadvantage of advertising. Oligopolists can also compete with one another, by using their supernormal profits to invest in research and development. Improved products can allow oligopolists to gain market share with non-price competition.

Strategies, when facing oligopolistic suppliers, are dominated by 2 main theories: the Cournot model or the Bertrand model. The latter is often criticized, because its outcome is only consistent what is observed, when a single buyer faces multiple suppliers (McDowell et al., 2012). The Cournot model describes how oligopolistic suppliers compete, by deciding on an output for supply. The model assumes suppliers decide independently on their output, on the basis of their expected demand. There is no collusion. Typically, Cournot competition results in higher prices, due to lower supplied quantities when compared to perfect competition. Firms do not compete on price, but merely on quantities supplied. A reaction curve (Figure 10) shows how firms compete with each other on quantities, resulting in a Nash equilibrium output. Although outputs are higher than they would be in a monopolistic market, its output is significantly lower than the perfect competition output.

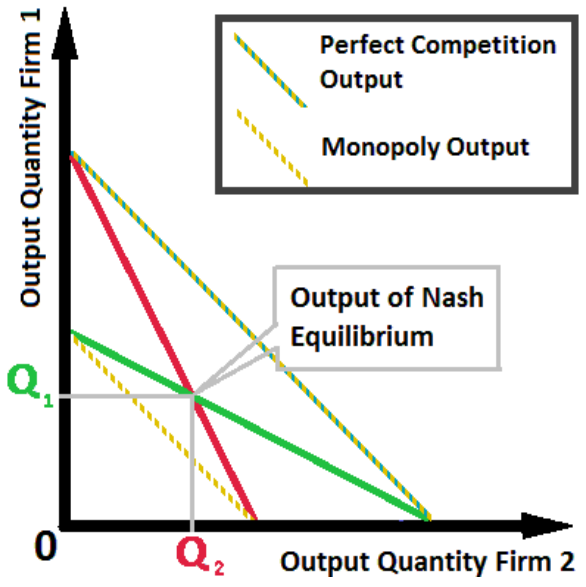

Figure 10: Reaction Curve of two Firms choosing their outputs independently (Cournot Model)

There is definitely room for exerting strategic behavior, by buyers facing an oligopoly. This behavior aims to increase supplied quantities,

thereby decreasing pricing levels. As oligopolists decide on their outputs on expected demand, the most convenient way to influence expected demand is by information sharing. Full information sharing among buyers and suppliers can have ambiguity results (Richter, 2013). If an industry nears its capacity constraints, information sharing will reduce consumer surplus (i.e. increases prices for buyers). However, if the industry does not face capacity constraints, full information sharing will increase consumer surplus, and buyers will be better off. It depends on the current market demand, relative to the capacity of the suppliers, whether or not to share information on future demands. The following strategies have been derived for buyers facing oligopolists:

Strategy 4: If an industry of suppliers nears its capacity constraints, do not share information about the future demand for goods & services.

Strategy 5: If an industry of suppliers does not face capacity constraints, share information about future demand for goods & services.

If there is perfect competition among buyers (i.e. individual buyers do not have significant market share), buyers must collude in order for these strategies to have significant effects.

2.3.4 MONOPOLISTIC SUPPLIERS

A monopoly, meaning there is only one supplier within a specific industry, is the most extreme form of imperfect competition. The monopolist maximizes profit in exactly the same way as a perfectly competitive firm would do; by determining output where marginal revenue equals marginal cost. The crucial difference between the two is, whereas marginal revenues equals the market price for a perfectly competitive firm, this is always less than the market price for a monopolist. A monopolist will only earn an economic profit when price exceeds total average cost, and this is its profit-maximizing level of output. It's inefficient because its profit maximizing price is greater than its marginal cost. This is a result of monopolists facing a downward sloping demand curve and if it want to increase its sells it will also have to decrease its unit price.

Monopolies produce less output compared to perfect competition and oligopolistic competition. This could give incentives for governments to legislate monopolies out of existence. Despite of numerous laws to improve competition among firms, monopolies still exist. One reason is, it would be ironic for governments to ban monopolies, which they themselves have often created. Another reason for monopolies still existing are natural monopolies, which are a product of market competition. They are characterized by relatively large fixed costs compared to the small market size.

Monopolists can increase social surplus by non-linear pricing. This strategy uses price discrimination: the charging of different prices to different buyers for the same good or service. Buyers with a low willingness to pay (or low reservation price) can get a lower than average price, but then will face a hurdle. Buyers with a higher than average willingness to pay can be charged a higher than average price, but will not face a hurdle. A classic example of price discrimination is the airline industry, where buyers with a lower willingness to pay acquire cheap tickets in exchange for the hurdle of booking months in advance. Buyers with a higher willingness to pay acquire more expensive tickets, but have the advantage of being able to book a week up front.

In order to apply price discrimination there are 2 things necessary:

1. There is a difference in demand between different groups.
2. There is an absence of the possibility of re-sale between purchasers.

There are 2 obstacles that need to be overcome before price discrimination can take place.

1. Sellers must know exactly how much each buyer is willing to pay.
2. Those who are willing to pay a higher price need to be excluded from buying at a low price.

2.4 DATA COLLECTION

In this Section, data collection is done to explore the level of competition among buyers and suppliers in large industrial projects. Data is collected through questionnaires. These questionnaires are developed to reveal the level of competition for the NKNK project of CB&I, but can be generalized for similar projects in the petrochemical industry.

2.4.1 PURCHASE ORDER CATEGORIES

The bottleneck, in accurately determining market characteristics of suppliers, is the different nature of the large number of purchase orders involved in these projects. The purchase orders need to be categorized in order to analyze the supplier's and buyer's market. The different categories of purchase orders are determined according to data provided by procurement managers within CB&I. This data contains a preliminary evaluation of all purchase orders needed for the NKNK project, based to a large extent on a reference project (ECC). This data will be used throughout this thesis. The most abundant categories are selected. The findings are summarized in Table 2. It shows 4 main categories which are divided into sub-categories.

Table 2: Purchase Orders divided into different Categories

Category	Total	Category	Total
Equipment Materials	**117**	**Electrical Materials**	**17**
Static	*48*	*Cables*	*6*
Rotating	*43*	*Switchgears & Transformers*	*6*
Other	*26*	*Other*	*5*
Instrument Materials	**22**	**Piping Materials**	**106**
Metering & Analyzers	*8*	*Bore Fittings & Pipes*	*40*
Instrument Valves	*5*	*Valves*	*19*
Other	*9*	*Other*	*47*

It is tried to pool a reasonable set of purchase orders into each category. This was mainly done on the basis of the description of the purchase orders. A second tool for pooling purchase orders (e.g. metering pooled with analyzers) is by determining whether purchase orders had similar potential suppliers. All purchase orders pooled as 'other' did not have enough similarities in order to pool them for the use in questionnaires, and are therefore not in the scope of this data collection method. The categories, that are decided upon to use in the questionnaires, are explained below. Expert knowledge

from the planning and project control manager of CB&I gave insights that led to the division of two categories into small and large parts.

- **Static Equipment:** This is equipment in an industrial plant which remains static (i.e. does not have moving parts) during the course of operation. Examples are heat exchangers, columns and vessels. There are significant differences expected in the market characteristic of small and large static equipment, hence the category will be separated into **Small Static Equipment** and **Large Static Equipment**.
- **Rotating Equipment:** This is equipment in an industrial plant which is used to add kinetic energy to a process. Examples are pumps and compressors. There are large differences expected in the market characteristics of small and large rotating equipment, hence the category will be separated into **Small Rotating Equipment** and **Large Rotating Equipment**.
- **Electrical Materials:** These are materials in an industrial plant that build up the electrical circuit. The most basic are the electrical **Cables,** which is in a separate category. Another subcategory is **Switchgears & Transformers**. Switchgears and Transformers are pooled, because they have almost identical potential suppliers. Switchgears are electrical disconnect switches, fuses or circuit breakers for the protection and isolation of electrical equipment. Transformers are static devices that are essential for the transmission, distribution and utilization of electrical energy.
- **Instrument Materials:** Instrument materials are all instruments used for the measurement, monitoring, and control of flows, pressure, and temperature. **Metering and analyzers** involve flow meters, level gauges, temperature, and similar monitoring equipment for process characteristics. The **Instrument Valves** actually control these process characteristics, to ensure the plant operates in the desired conditions.
- **Piping Materials:** Piping materials are involved in the distribution of substances within a plant, which is usually done through a network of hollow cylinders **(Pipes)**. **Bore Fittings** are used in this network to make pipe-to-pipe connections. **Valves** are devices that allow regulation of flows by closing, opening or partially blocking a passageway of a stream.

On the basis of these categories, five different questionnaires are developed, in which the ten sub-categories described in this Chapter are addressed. The questionnaires incorporates statements involving the theory on imperfect competition, described in Chapter 2.3. It is done using predominantly a 7 point Likert Scale. An example of the questionnaire for static equipment is shown in APPENDIX B. The other questionnaires are basically a duplication of this questionnaire.

2.4.2 UNITS OF ANALYSIS

The units of analysis, the sources where the data is retrieved from, are described in this Chapter. The units of analysis are divided in Respondent Category 1 and 2, where the first are managerial respondents and the latter are engineering respondents. It is explained why and how these were selected in the next two Sub-Sections. Table 3 summarizes for each purchase order category, whom the units of analysis are, according to their formal title within CB&I. For the sake of privacy their names are not published.

Table 3: Questionnaire Categories and their Respondents

Category	Sub-Category	Respondent 1 Title	Respondent 2 Title
Static Equipment	Small Static Equipment	Senior Project Procurement Manager	Mechanical Engineering Specialist
	Large Static Equipment		
Rotating Equipment	Small Rotating Equipment	Project Procurement Director	Principal Engineer Rotating Equipment
	Large Rotating Equipment		
Electrical Materials	Cables	Sourcing and Expediting Manager	Lead Electrical Engineer
	Switchgears & Transformers		
Instrument Materials	Metering & Analyzers	Project Procurement Manager	Lead Instruments and Control Systems Engineer
	Instrument Valves		
Piping	Bore Fittings & Pipes	Senior Buyer and Procurement Analyst	Section Leader Piping Engineering
	Valves		

2.4.2.1 RESPONDENT CATEGORY 1: PROCUREMENT MANAGERS & SENIOR BUYERS

Expert knowledge is needed in order to get a good view on the supplier and buyers' market of the different categories. Knowing the number of suppliers and buyers within a particular industry is not sufficient to determine the level of competition. Not to mention the enormous amount of effort that needs to be undertaken in order to accurately acquiring this data. The level of competition needs to be known to determine suitable sourcing strategies.

For the purpose of these questionnaires it is straightforward to select senior buyers and procurement managers, as those are the most knowledgeable experts in the field of sourcing. They are required to have years of experience before being allowed to occupy such a position. Therefore the questionnaires are set out at five procurement managers, shown in column 'Respondent 1 Title' in Table 3. To avoid handing over the questionnaires randomly, each questioned manager is requested to indicate their preferred subject for a questionnaire (e.g. Static Equipment). Thereby a set of results will be obtained that, besides representing years of experience, is likely to represent an area of expertise of the questionnaire respondents.

2.4.2.2 RESPONDENTS CATEGORY 2: ENGINEERS

In the explorative search for questionnaire participants signals were received: using only procurement managers for questionnaires, would not be fully representative for the sourcing process. Engineers are often involved with suppliers, making a pre-selection on suitable potential suppliers per purchase order. For example, they determine which suppliers can meet the required standards. The suitable suppliers are communicated to the procurement manager, which therefore does not see all possible suppliers in the field. For this reason it is suggested to also incorporate Engineers, specialized in each category, in the questionnaires. A more richer and solid set of results will be obtained. If significant differences in insights are revealed, between the procurement managers and engineers, it will be

examined why these differences occur. It is tried to get results on which both respondent categories can agree upon.

2.4.2.3 SELECTION OF SUITABLE RESPONDENTS

Through discussions with the Director Procurement Europe (CB&I), suitable candidates were selected for 'Respondents Category 1'. Most Procurement Managers and Senior Buyers would have enough knowledge of each purchase order category to answer the questionnaires. In order to get the most reliable results possible, they were given the opportunity to indicate their category of preference. The Project Procurement Director, which also participates in the questionnaire, advised on the selection of 'Respondents Category 2'. Through his knowledge experienced engineers were selected, specialized in each category. An overview of the questionnaires and their respondents is given in Table 3.

2.5 DATA ANALYSIS

Once the questionnaire respondents handed in the hardcopy questionnaires, they are translated to an excel file. All scores are summed up, separately for the supply and demand side, to calculate a total score. The questionnaires are designed in a manner that an answer to a question with a high value always indicate imperfect competition, and low values indicate perfect competition. As it is a 7-point Likert scale, when the total score is divided by the total number of questions, one acquires a measure for the degree of competition on the different purchase order categories for buyers and suppliers. Because the questionnaires are limited to two respondents per category, it results in a simple lower bound and an upper bound. These bounds indicate differences in perceived competition among procurement managers and engineers.

2.5.1 STATIC EQUIPMENT; SMALL AND LARGE

The engineer estimated a higher degree of competition for small and large static equipment than the procurement manager. This appeared to be so for both the supply as the demand side. As shown in Figure 11, there is no significant difference between degrees of demand side competition for large and small static equipment. This is also the case for the supply side. The differences in perception between the two respondents are quite large, an average difference of 0.95 on a 7-point Likert scale equals a difference of over 13% for the supply side. The demand side has an average difference of 1.5, a relative difference of 21%. However, a Likert scale is a subjective measure, so differences in perception of respondents are to be expected. Both respondents indicated a higher degree, and to the same relative extend, of competition between the suppliers, when compared to buyers. This shows some consistency in the results, where it can be concluded that buyers have more market power than suppliers. There could be some form of oligopsony among buyers, where the supply side is likely to be in a more perfect competitive environment.

Because of the relatively large differences in perceptions, the market characteristics of this category are discussed more in depth with the engineer as well as the procurement manager. It turned out that the market for small- as well as large static equipment is hard to generalize. For example static equipment involves vessels and columns. Vessels are often not seen as highly specialized equipment, which can be delivered by a relatively large number of suppliers. Also the demand for vessels arises from a range of industries. Columns, and especially large columns, are more specialized equipment that involves a higher level engineering design. For some columns there are only 2 or 3 potential

suppliers on the globe. There are however more 'standard' columns that are often used in the petrochemical industry. These are less unique and can be delivered by a larger number of suppliers. Note that almost all are custom made, but some require a more specialized design than others.

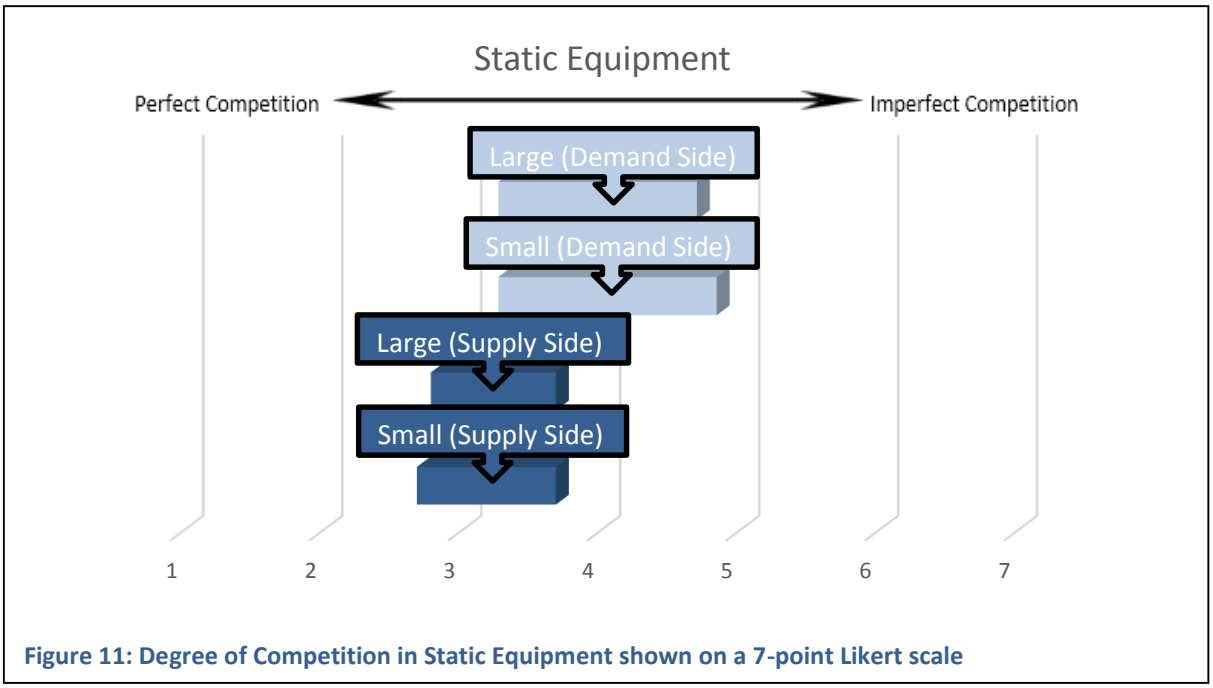

Figure 11: Degree of Competition in Static Equipment shown on a 7-point Likert scale

2.5.2 ROTATING EQUIPMENT; SMALL AND LARGE

The engineer estimated a higher degree of competition for small and large rotating equipment than the procurement manager, for both the supply as the demand side. Figure 12 shows a significant difference on competitiveness on the demand side, among small and large rotating equipment. For small rotating equipment the respondents have a relative average difference in perception of 10%, which is quite high, but not unreasonable. For large rotating equipment the difference on demand side competition is high (an almost 30% difference between respondents). The engineer experiences a

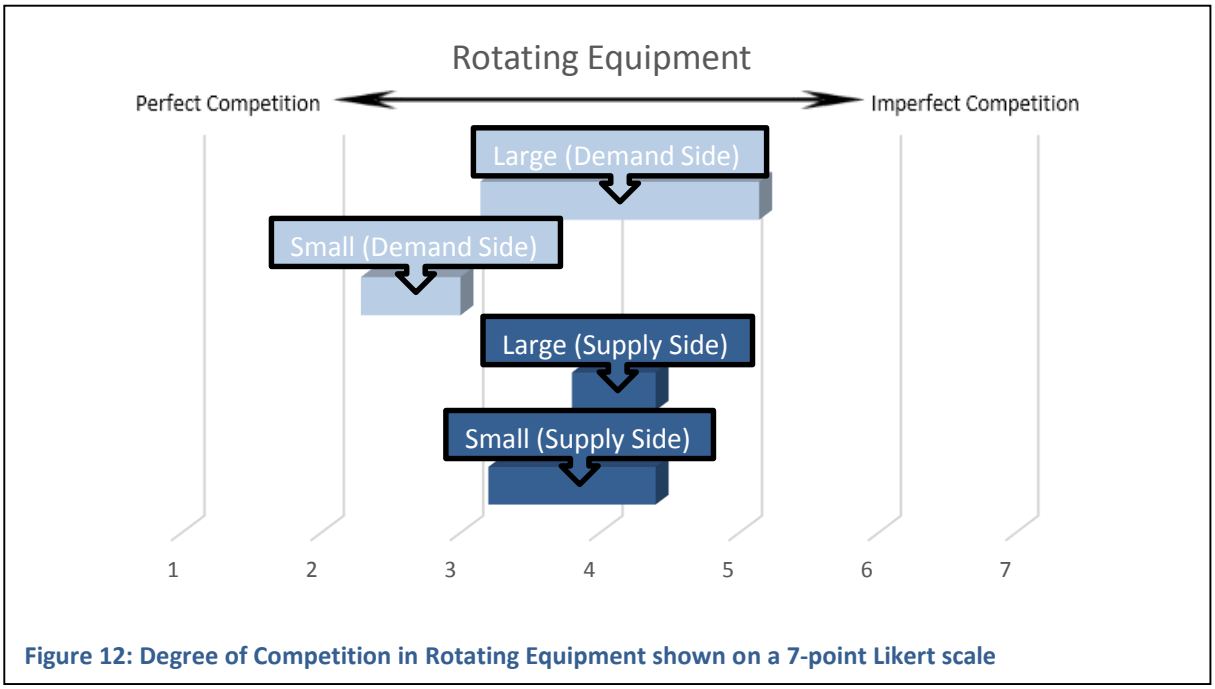

Figure 12: Degree of Competition in Rotating Equipment shown on a 7-point Likert scale

market towards perfect competition and the procurement manager indicates some form of oligopsony. The results for the supply side are less convincing, although the differences in perception are significantly lower when compared to the demand side (average relative difference of 13% versus 19%). The engineer sees a slightly more competitive supplier market for small and large rotating equipment compared to the procurement manager.

The buyer's market for large rotating equipment is perceived very differently by the engineer, when compared to how the procurement manager perceives the market. A further discussion with the engineer indicated that he had only minor experience with other buyers. He did not see that other buyers are closely monitored, because of the fierce competition among buyers. The procurement manager convincingly indicated that this was the case.

2.5.3 ELECTRICAL MATERIALS

The engineer has indicated a higher degree of competition (thus a lower position on the Likert scale) for all sub-categories, when compared to the procurement manager. This is seen for the demand side as well as the supply side (Figure 13). These differences in perception are consistent with the analyses of static and rotating equipment, but are smaller. The largest difference in perception is for the supply side of cables (14% difference), but this is no shocking difference. Obviously, both respondents indicate there is a high degree towards imperfect competition among suppliers of cables. In addition they indicate, by a low position on the Likert scale for cables, that there is a high degree of competition between buyers. A similar degree of competition is indicated for Switchgears & Transformers, but the supply side of this sub-category also seems to be more towards a competitive state.

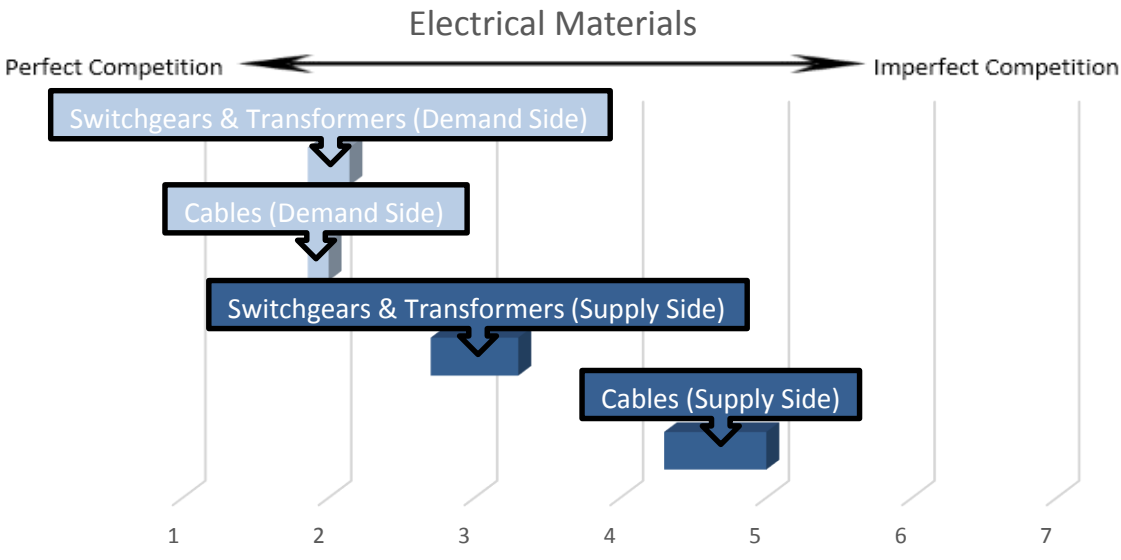

Figure 13: Degree of Competition in Electrical Materials shown on a 7-point Likert scale

2.5.4 INSTRUMENT MATERIALS

There are no significant differences between the perceptions of the participants in the degree if competition of instrument materials, for the demand- as well as the supply side. As indicated in Figure 14, the differences in perception of competitiveness range from 0 to 4% (except for metering and

analyzers on the supply side, which is 10%). There is no clear evidence that indicates oligopsonistic behavior of firms on the demand side. Buyers in the market for instrument materials seem to be in a more competitive state, when compared to suppliers. There could be a very mild form of market power on the supply side. This is equally likely to be the case for instrument valves as for metering and analyzers, but it is not very convincingly to be an oligopolistic market. It seems that suppliers have

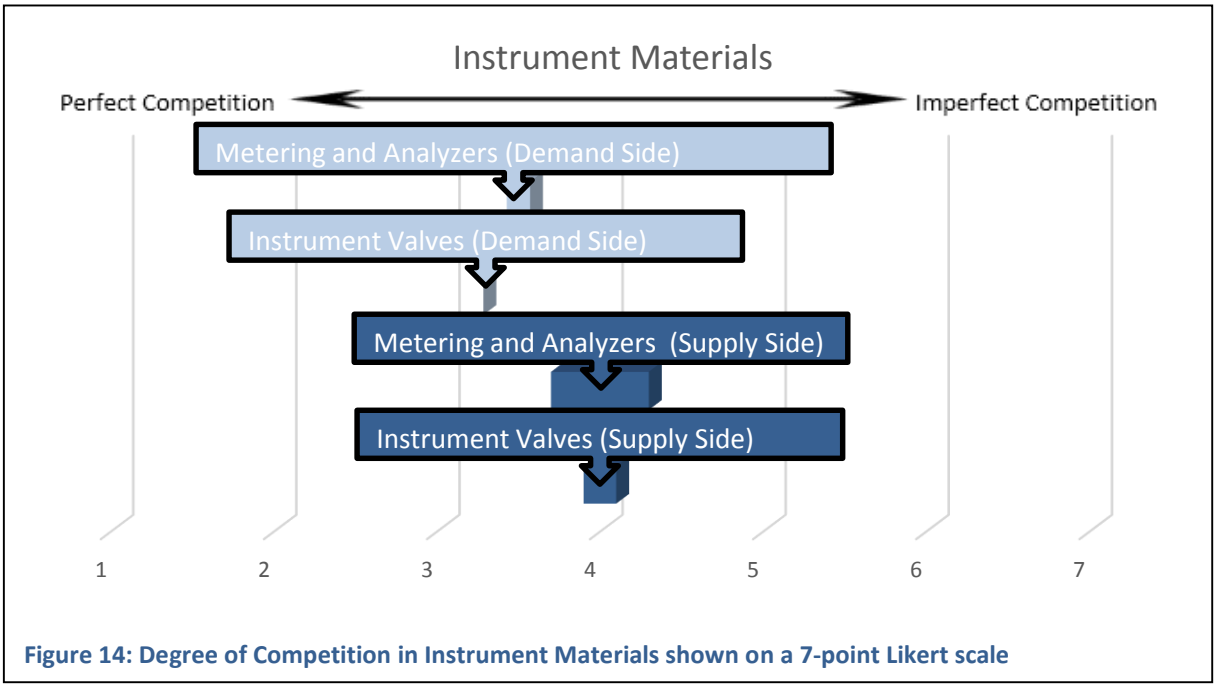

Figure 14: Degree of Competition in Instrument Materials shown on a 7-point Likert scale

some advantage over buyers in both purchase order sub-categories.

2.5.5 PIPING MATERIALS

The results of the piping materials questionnaires are shown in Figure 15. One important observation is that both the engineer as well as the procurement manager have given equal answers to the

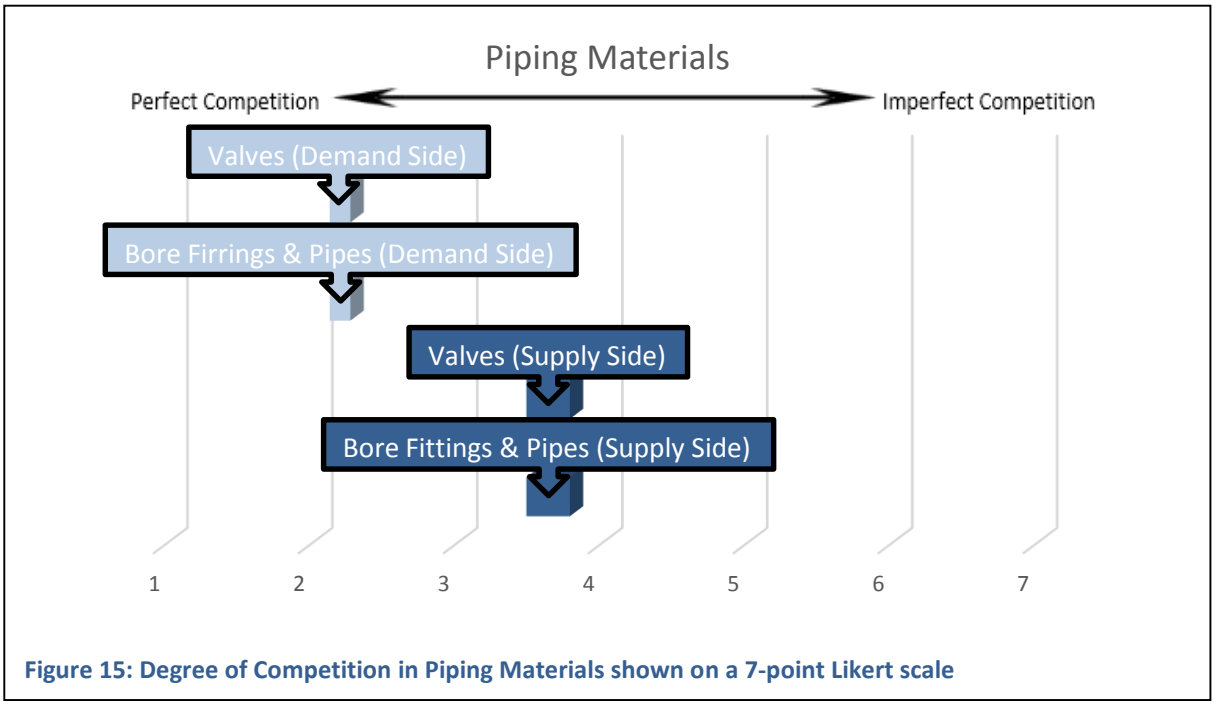

Figure 15: Degree of Competition in Piping Materials shown on a 7-point Likert scale

different sub categories, i.e. both respondents indicate there is no difference in the degree of competitiveness in the markets for 'Valves' and 'Bore Fittings & Pipes'. The respondents indicated that this applies to the demand- as well as the supply side. Hence the ranges shown in Figure 15 are exactly the same for the categories. On the demand side the relative range is somewhat smaller (2%), when compared to the demand side (4%), but there is no significant difference in perception between the two respondents. When comparing supply and demand, it is clear that the competition among buyers is towards perfect competition. This is in contrast to the supply side, where there are some weak signs indicating an oligopolistic market.

2.6 SUMMARY OF DATA ANALYSIS

The findings of Section 2.5 are summarized for the supply and demand side in Table 4. In this table the averages are taken of the perceptions of the procurement managers and engineers of each sub-category. Also, for comparison of the different categories, averages are shown of the different categories.

Table 4: Supply & Demand Side Summary of Questionnaire Data Analysis

Category	Sub-Category	Averages (Supply)		Averages (Demand)	
Static Equipment	Small Static Equipment	3.2	3.2	4.1	4.0
	Large Static Equipment	3.3		4.0	
Rotating Equipment	Small Rotating Equipment	3.8	4.0	2.6	3.4
	Large Rotating Equipment	4.1		4.1	
Electrical Materials	Cables	4.7	3.8	1.9	2.0
	Switchgears & Transformers	3		2.0	
Instrument Materials	Metering & Analyzers	4.0	4.0	3.5	3.4
	Instrument Valves	4.0		3.3	
Piping Materials	Bore Fittings & Pipes	3.7	3.7	2.2	2.2
	Valves	3.7		2.2	

For the sub-categories of static equipment, instrument materials and piping materials the averages of the supply as well as the demand side do not differ at all, or only minimal differences are noticeable. For the sub-categories of rotating equipment (demand side) and electrical materials (supply side) clear differences can be seen.

On the supply side the most competitive industry seems to be for switchgears & transformers. Also the suppliers market for small and large static equipment seems to be more significantly more competitive than other categories. The least competitive industry on the supply side is the cable industry, followed by large rotating equipment and instrument materials. The other categories seem to be somewhere in the middle

On the demand side, the most competitive industry is for cables. Also for the markets of bore fittings & pipes, valves, switchgears & transformers, and small rotating equipment (to a lesser extend) respondents indicated a more than average competition between buyers. The least competitive

industries on the demand side are for large rotating equipment and static equipment (small and large). The other categories seem to be somewhere in the middle.

The results are plotted in a competition chart, shown in Figure 16. The horizontal axis indicates the degree of competition on the supply side and the vertical axis indicates the degree of competition on the demand side. The midpoint of the graph is the average value of all categories of the supply and demand side. In this way it can be clearly shown how different sub-categories differ from the average values. The range of the graph is determined by the minimum and maximum average competition level values of the supply and the demand side. The sub-categories are plotted using excel, and correspond with the values shown in Table 4. Constructing the graph in this way allows an easy identification of sub-categories which differ significantly from other sub-categories.

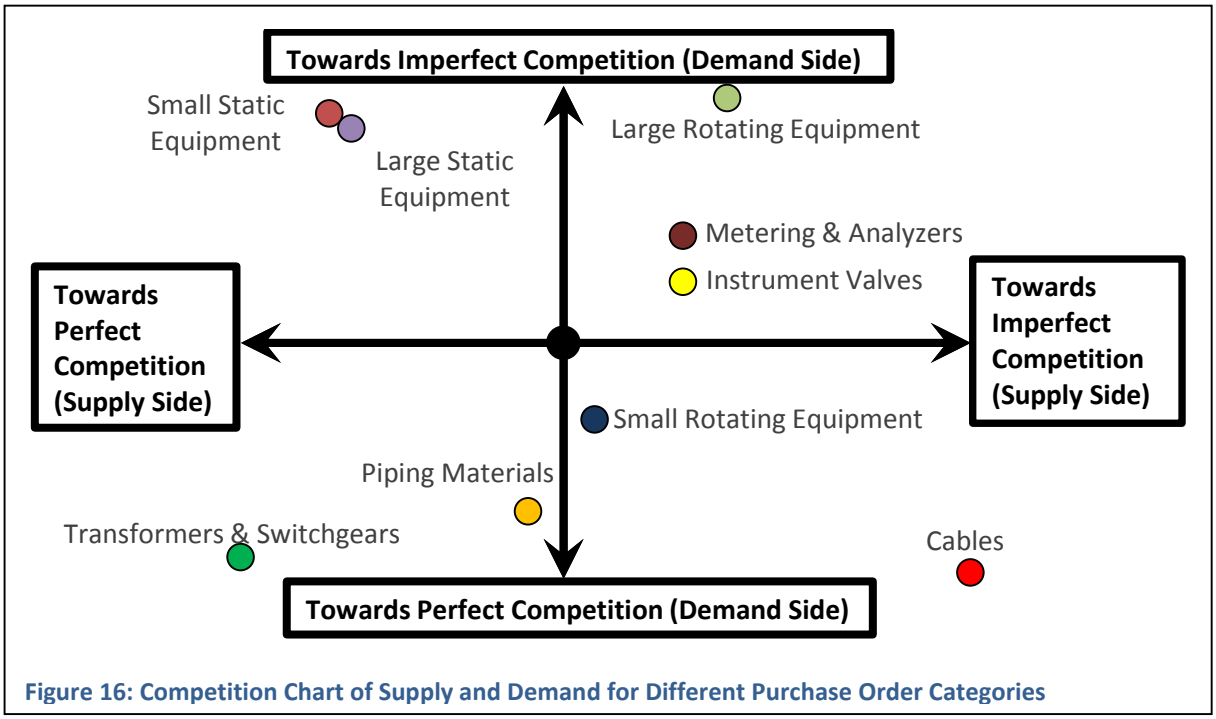

Figure 16: Competition Chart of Supply and Demand for Different Purchase Order Categories

There is no significant difference between the sub-categories (large and small) of static equipment. They both appear on approximately the same location on the competition chart. These categories face relatively high values towards imperfect competition on the demand side. In addition there are high values towards perfect competition on the supply side. This indicates that buyers in this market have more bargaining power than suppliers. Buyers can therefore exert strategic behavior.

Large rotating equipment is experiencing slightly imperfect competition on the supply side. On the demand side it has the highest value towards imperfect competition of all categories. This indicates that buyers will have more bargaining power than suppliers. Put differently suppliers rely more heavily on buyers than vice versa. There is probably room for strategic behavior of buyers.

Cables is a sub-category that clearly differs significantly from the average middle point. Sub-category cables has the highest value towards imperfect competition on the supply side, and the highest value towards perfect competition on the demand side. This indicates that buyers have little market power, but face suppliers with market power (oligopolists). Consequently, buyers of cables are very likely to pay a higher price, than they would in a perfectly competitive environment. A strategic sourcing strategy is suggested.

Another sub-category of electrical materials, which significantly differs from other sub-categories, is switchgears & transformers. This sub-category involves relatively competitive buyers, which face relatively competitive suppliers. Therefore this category is less likely to have deadweight losses due to profit (and not output) maximizing oligopolists and bargaining oligopsonists. There is little room for strategic behavior.

Metering & analyzers and instrument valves have a position towards slightly imperfect competition on the demand- as well as the supply side. Suppliers and buyers in these categories both have some bargaining power, but as a consequence both are also dependent on each other. Both sides must be careful to exert strategic behavior, as this could backfire.

Piping materials (both sub-categories of piping materials have the exact same position) and small rotating equipment face more or less average competition on the supply side. On the demand side, suppliers of these categories tend to face more than average competitive behavior of buyers. Buyers of piping materials face a slightly higher competition level. The suppliers here seem to have a slight advantage, and strategic behavior of buyers is suggested to minimize the effect of supplier power.

2.7 APPLYING SOURCING STRATEGIES ON PURCHASE ORDER CATEGORIES

In this Section an attempt is done to connect the different sourcing strategies explained in Section 2.3, with the results from the questionnaire summarized in Section 2.6.

For small static equipment & large static equipment almost equal conclusions are drawn from the analysis. Buyers of small and large static equipment seem to have bargaining power over the suppliers. This means that strategies can be used by buyers to reduce sourcing costs. Buyers should commit to a single sourcing strategy, to induce an all-out competition (indicated by strategy 3 in Sub-Section 2.3.2). A single sourcing strategy will also be beneficial due to the highly specialized equipment that characterizes this category, which results in high fixed costs per delivered purchase order.

An oligopoly is facing an oligopsony, in the market for large rotating equipment. Buyers seem to have a slight advantage over suppliers in this category. A single sourcing strategy here might be necessary according to procurement managers and engineers. Some equipment, especially very large compressors, can only be single source as only 1 piece of equipment is needed for some projects. Buyers however can influence pricing to some extend by strategically communicating about their future demand expectations. This is indicated in Sub-Section 2.3.2 with strategy 4 and 5. These strategies involve sharing information when the supplier market is not near its capacity constraints, and do not share information when the suppliers market nears its capacity constraints.

Small rotating equipment and piping materials have a similar market characteristics on the supply and demand side. The supply side has more market power, compared to the demand side. As oligopolistic suppliers base their outputs (and their prices) on information, strategic sourcing strategies for these sub-categories involve information sharing. Strategy 4 or 5 must be undertaken (Sub-Section 2.3.3). These strategies involve sharing information when the supplier market is not near its capacity constraints, and do not share information when the suppliers market nears its capacity constraints. For small and rotating equipment, and even more for piping materials, the buyers' market is so defragmented that collusion of buyers might be necessary for these strategies to have effect.

Cables is the most extreme case of all sub-categories. Suppliers are in a very favorable position, where buyers do not have significant bargaining power. Supra-normal profits of suppliers are to be expected here. In order for buyers to have some bargaining power, they must collude and share a similar strategy. Only under high forms of collusion one can commit to the strategies suggested, when facing oligopolistic suppliers (Sub-Section 2.3.3). It is most convenient to stick to a single sourcing strategy per type of cable, as changing to a multiple sourcing strategy is not likely to have effect in a competitive buyers' market environment, and only increases transaction costs. One can commit however to different suppliers per type of cable. When different types of cables are not sourced from the same supplier, one can benefit from a quasi-multiple sourcing strategy (these benefits are indicated in Sub-Section 2.2.2).

For switchgears & transformers strategic sourcing is the least relevant of all categories, because both the supply and the demand side is in relatively high levels of competition. Therefore both do not have significant bargaining power. No strategies are suggested.

Both sub-categories of instrument materials (metering & analyzers and instrument valves) face similar market characteristics. Both have a relatively mild imperfect competitive buyers facing some form of imperfect competitive suppliers, but not really convincingly. One has no significant bargaining power over the other, but some form of strategic sourcing should be done. A multiple sourcing strategy can be beneficial for buyers, where their demand is divided into tranches and multiple suppliers. Depending on the project characteristics either Strategy 1 or 2 can be used, as is elaborated upon in Sub-Section 2.3.2.

2.8 LIMITIATIONS IN APPLYING SOURCING STRATEGIES

The outcomes of the questionnaires, including suggested sourcing strategies, are discussed with the respondents. It revealed serious limitations in applying these suggested sourcing strategies. The most important limitations are seen for strategy 1 and 2.

Strategy 1 suggests to split the demand in demand tranches over time. For most purchase order categories this is not possible to implement at the same supplier, because the division into tranches is inefficient and impractical. This is especially the case for Long Lead Equipment, which are purchase orders identified to have a delivery time long enough to directly affect the latency between the initiation and execution of projects. Examples of Long Lead Equipment are large compressors, turbines, generators, and control systems. These highly customized purchase orders are allocated in an early stage in the project, to avoid latency. If one would split demand, this will only result in more latency. Applying strategy 1 can be done, and it is done, for more standard purchase orders. These are informally known within CB&I as commodity purchase orders. With these commodity items strategy 1 is often applied, and dividing the demand in demand tranches over time periods is known as purchase orders on a Call of Order basis. Besides the advantage of not overloading suppliers with demand, this also reduces storing costs on site for equipment that is not needed for a certain period.

Strategy 2 suggests to split the demand into demand tranches over different regions. In practice this will mean that the demand is split over different suppliers. Firstly, due to the highly customized nature of the large number of purchase orders, it is not favorable to have multiple suppliers designing the same equipment. E.g. designing one and constructing one compressor costs 10 million USD, constructing five compressors with the same design costs 20 million USD. It is therefore not cost

efficient to divide these purchase orders over multiple suppliers. A second reason for not splitting the demand over multiple suppliers, is the time and effort involved with evaluating the bids. MTOs (Made-to-Order) purchase orders are designed and fabricated according to the specifications of CB&I, and it must be evaluated whether the bids of suppliers have the desired specifications. This is an iterative process between buyer and supplier, and it cost valuable time. For less customized purchase orders (the commodity items) this splitting of demands over different suppliers can be done. Although this may lead in initial cost reductions, this is not a preferred strategy. An example to illustrate this is piping materials, which is highly standardized equipment. These purchase orders consists of a large number of smaller parts, making it a logistical challenge to order the materials at the right moment in time, transporting them to site, storing them on site, and distribute them over the site where they are needed. Each part is labeled and can thereby be tracked. This logistical challenge becomes a logistical nightmare, when multiple suppliers are involved with the same purchase order.

Most frequently strategy 3 is applied, relying on single sourcing. This does not imply that only 1 supplier is taken into account. A selection of suppliers is made for each purchase order, and inquiries are sent to these suppliers. When all bids are received, often the bids with too low or too high values are discarded, because they are outliers, probably not reflecting accurately the specifications of the purchase orders. The remaining bids are evaluated whether the design is appropriate. In addition these are tested on their commercial validity. Frequently the design is incomplete and some adjustments need to be made on the bid by the supplier. When the supplier has modified its bid it is evaluated again. Bids still not meeting requirements are discarded. Of the remaining bids, the supplier which offered the bid with the lowest value will win the tender.

2.9 CONCLUSIONS

In this Chapter conclusions are drawn on the market characteristics of the purchase order categories, which are explored in this Chapter. In addition, their strategic importance is discussed.

Firstly, the importance of strategic sourcing is underlined. It is underpinned why a firm should consider strategic sourcing. The most important reason is cost reduction. A cyclical strategic sourcing process is suggested in order to systematically and continuously adjust and improve a firm's sourcing strategy.

Secondly, two general sourcing methods are compared: single sourcing and multiple sourcing. The advantages and disadvantages of both methods are described. A single sourcing strategy mostly benefits supplier-buyer relationships, where a multiple sourcing strategy can improve competitive pricing. In addition, multiple sourcing is a method of risk reduction.

Thirdly, different concentration levels of competition are defined as the market share of the set of largest suppliers within an industry. In these concentration levels there is perfect competition (0-50%), oligopolistic Competition (50-90%), and monopolies (90-100%). In total there are five strategies suggested for buyers facing these forms of competition. The relative size of the buyer is decisive in which strategy should be applied.

Fourthly, data collection is done through questionnaires on a 7 point Likert scale. The questionnaires are conducted with industry experts. Procurement managers as well as engineers are involved in the questionnaires, to reduce bias in the results. The industry's sourcing activities are divided into four different purchase order categories: equipment materials (static and rotating Equipment), electrical

materials, instrument materials and piping materials, which in turn are divided into sub-categories. Both the supply- as well as the demand side, of the different categories, are studied.

After these questionnaires had been conducted a data analysis is done. Engineers constantly perceived a more competitive market, compared to the perception of procurement managers for the same purchase order category. This can be explained by the pre-selection of suppliers engineers make, before the procurement manager comes into play. Sub-category cables appeared to have the most extreme form of imperfect competition on the supply side, as well as the most extreme form of perfect competition on the demand side. Large rotating equipment has some form of imperfect competition on the supply side, but buyers in this market seem to have more bargaining power. The market characteristics of small and large static equipment are perceived almost equal, which moves towards imperfect competition on the demand side, and towards perfect competition on the supply side. Switchgears & transformers face relatively high levels of competition on the supply and demand side. The market characteristics for the sub-categories of piping materials are perceived exactly equal, and shows a slight advantage for suppliers over buyers. Other categories are somewhere in the middle.

Lastly sourcing strategies are selected on the basis of the bargaining power buyers and suppliers have according to data analysis of the questionnaires. The strategies suggested include collusion, single and multiple sourcing, and strategic information sharing. No strategy is suggested for Switchgears & Transformers, due to its competitive environment. The strategies suggested are analyzed on their practical applicability. It turns out that, due to the nature of the business, a multiple sourcing strategy is not appropriate for the majority of purchase orders. Dividing purchase orders in tranches can backfire, resulting in latency, higher costs, and logistical nightmares. Most frequently a set of bids is evaluated, and the most attractive one is selected. This single source strategy is used always for a single purchase order, with the exception of commodity items.

CHAPTER 3 DESCRIPTIVE STATISTICS ON SUPPLIERS

This Chapter gives an overview of the sourcing possibilities per purchase order type, with respect to geographical location. This overview is given through descriptive statistics on suppliers. In Section 3.1 it is underpinned, why CB&I could benefit in selecting more than one supplier for each purchase order. Also the limitations in selecting suppliers are underpinned. Data is collected, to evaluate the selection of suppliers, and its method is described in Section 3.2. Data is collected from procurement managers, which they see as potential suppliers for the NKNK project. The number of potential suppliers per purchase order, and the country in which they are situated, are shown in Section 3.3. In Section 3.4 it is tested whether this corresponds to the outcome of the questionnaires (which are conducted in 0), using linear regression for proposition testing. Data is also collected from the reference ECC project in Section 3.5, in order to compare different project contexts and their corresponding supplier characteristics per purchase order. Conclusions are drawn in Section 3.6.

3.1 REASONING FOR AND LIMITATIONS OF THE SELECTION OF SUPPLIERS

In general one can say, the more bids are received, the higher the possibility of a low valued quotation. Although this may be true, no attempt is done to select all suppliers in the world. The project context can play a large role in the selection of suppliers. Therefore this does not imply that all potential suppliers of a purchase order will be inquired for a bid. This has 2 reasons. The first reason is a list of suppliers which match the requirements for a project, with respect quality, trust, and previous experiences. Only suppliers noted in this 'Approved Vendor List' can be used as a supplier for a project. A second reason for not selecting some potential suppliers are financial constraints. These constraints are discussed in more depth in Chapter 6. Financial restrictions result in a bias towards selecting suppliers, where budget is likely to be available, ignoring these restrictions could result in a forced single source supplier.

Selection of suppliers is done on the basis of approved vendor list. Although there could be more suppliers in the world for a particular piece of equipment, not every supplier is a potential supplier. In the early stages of a project, in consultation with the client, an approved vendor list is compiled. This is done on the basis of quality standards, ISO certifications, and previous experiences with suppliers. It is quite common to have fewer than 5 suppliers listed on the approved vendor list per purchase order. Selecting more than 5 suppliers is not possible, although it may be desired. To indicate the importance for suppliers to be noted in this approved vendor lists, a Korean supplier at the moment is offering ridiculously low tenders, seducing CB&I and the client for considering this 'not approved vendor'. Thereby this Korean supplier hopes to win the tender, prove its adequacy, and to acquire an approved vendor status.

Neglecting the financial constraints in selecting potential suppliers, could result a budgetary mismatch, i.e. a deficit of budget in one country and a surplus in another. This could result in problematic allocation of funds. For example CB&I once had a project with a budgetary mismatch, leaving a substantial amount of budget obligated to be spent in the USA. This budget needed to be used for a relatively expensive long lead equipment. Since budget was only available in the USA, CB&I was limited to the number of suppliers (3) in the USA that could deliver that equipment. Although the USA is a relatively expensive country, this should not become a very big problem as 3 suppliers is still reasonable. However, for the sake of transparency the ECA of the USA (named Export-Import Bank), published the budgets available of CB&I in each country and for which type of equipment that budget

is destined to be used. Suppliers in the USA have taken this information to their advantage, and acted in collusion. CB&I faced abnormal high bids from all 3 potential suppliers, but did not have the possibility to change to suppliers in other countries. They had to pay the prize, which had such a negative effect on the project that it barely made a profit.

In ideal cases, a buyer would like to inquire as much suppliers as possible. Doing so will increase its chance of receiving the lowest bid in the market. The amount of inquiries send to the market is not only limited due to the approved vendor list. It is also limited, because of the administrative burden involved with communicating with large numbers of suppliers. On the basis of the approved vendor lists, when there are more than approximately 10 suppliers, a refinement of the selection is done. However, this does not imply that each inquired supplier will place a bid. In extreme cases there could be only one or, even worse, no bid for a single purchase order. This indicates that the degree of competition, especially on the demand side, could be a determinant for the amount of selected suppliers. This single source could have severe impact on the country's budget. Secrecy is important in this business, as a supplier that knows it is single source will be in a very favorable position. Single source suppliers are notorious for charging abnormally high prices, when it publicly known they are single source. Therefore, sending inquiries to the market and evaluating bids is a highly confidential process. Any information leaking to suppliers would reveal their position and bargaining power.

3.2 DATA COLLECTION

In this Section the data that is be collected including its source, is discussed. With this data descriptive statistics on suppliers can be computed.

3.2.1 PURCHASE ORDERS, SUPPLIERS AND THEIR COUNTRIES

Data is collected from data sheets provided by procurement managers. In these data sheets potential suppliers for the NKNK project are listed, including their most likely manufacturing location (country). The suppliers are listed per purchase order ID, a number that is given to each type of equipment that is needed for a construction project. Also the purchase order type is listed. These types are described in more detail in Sub-Section 2.4.1. Each purchase order has a name, which is not used for descriptive statistics. It is merely to give a more meaningful description to the purchase order ID. For each purchase order a supplier, or a number of suppliers, is/are listed according to their commercial name. For each supplier, the country in which it is likely to manufacture its goods, is listed. Table 5 shows an example with 2 purchase orders, how the data collected looks like. Note that these are fictional supplier names for the sake of confidentiality.

Table 5: Example of a collected data sheet with Purchase Orders

Purchase order ID	Purchase order Type	Purchase Order Name	Supplier Name	Supplier Country
PO-1001	Rotating Equipment	Vacuum Unit	Indart	Netherlands
			Barbara	Japan
PO-1002	Static Equipment	Cold Boxes	Dorf	Germany
			Kabi	Japan

This data collection method is repeated for the ECC project, in order to make a comparison between two very similar projects. The data source is however slightly different. Per purchase order (which are essentially the same as those identified for NKNK), the suppliers to which bid requisitions are send are retrieved from the data base of CB&I. Eventually a similar type of table is retrieved from this data. In addition to this, as ECC is a completely finished project, data was collected on the suppliers that were eventually awarded the purchase order contracts. Using this data, a comparison can be made between different project contexts.

3.3 DESCTRIPTIVE STATISTICS ON POTENTIAL SUPPLIERS NKNK PROJECT

Based on a data analysis done on the NKNK project the number of potential suppliers, and their country of origin, can be mapped for the different purchase order categories stated in Sub-Section 2.4.1. The data set obtained is a selection done by CB&I, which they identify as potential suppliers for the NKNK project. The data was provided by procurement managers of CB&I. As it is not time- and cost wise efficient in this industry to evaluate each supplier on the world, there is a bias towards known suppliers in the region. Also the project context can play a role in the selection of suppliers. For example, budgetary constraints of ECAs are taken into account for the selection of potential suppliers: some suppliers cannot be used as they are located in countries where there probably is no budget available to source from.

3.3.1 EQUIPMENT MATERIALS

Firstly, the number of potential suppliers, which CB&I thought where suitable for purchase orders of equipment materials, are analyzed. This includes rotating, static and other (special) equipment. Using MS Excel the number of potential suppliers selected by CB&I is determined for each purchase order. A frequency can be derived for the number of potential suppliers per purchase order. This is done for each sub-category of equipment materials. The outcome is shown in Figure 17, where a total of 117 purchase orders for equipment materials are analyzed. The mode (the value that appears most frequent in the data set) is 6 potential suppliers, which has a frequency of 23. It also is shown in Figure 17 that this mode has its origins to a large extend from static equipment, and to a lesser extent from other equipment. The mode for rotating equipment is 5. The average value (calculated by dividing the sum-product of the number of potential suppliers and its frequencies (490) by the number of purchase orders (117)) for the total number of potential suppliers for equipment materials is 4.2, which is well

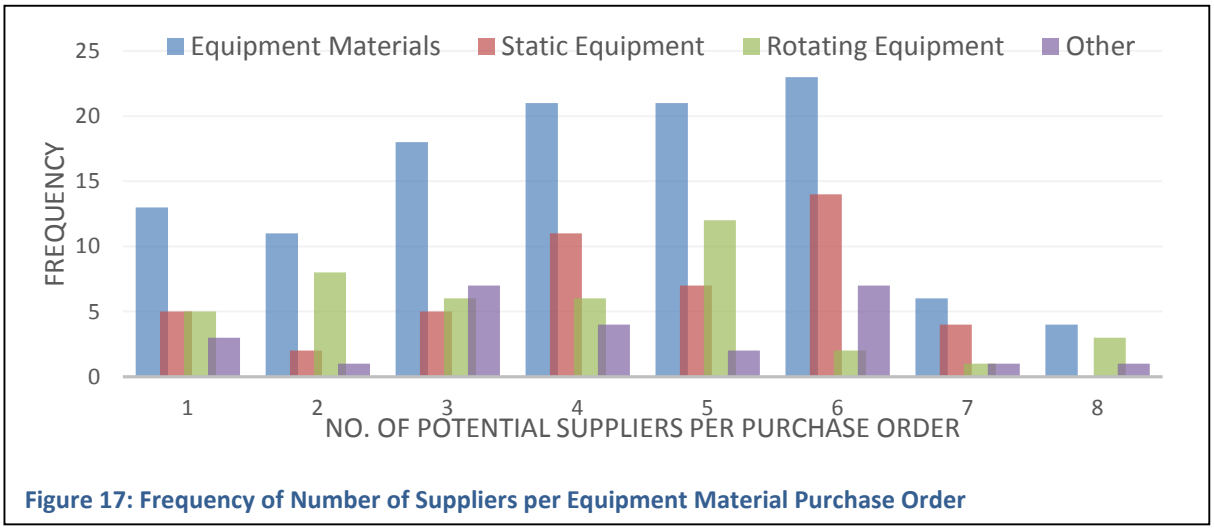

Figure 17: Frequency of Number of Suppliers per Equipment Material Purchase Order

below all modes. The average number of potential suppliers per purchase order differs for rotating equipment (4.0) and static equipment (4.5). The sub-category other represents a total of 22% of all purchase orders. The maximum number of potential suppliers for a purchase order is 8, which has its origins in rotating equipment and other equipment. Eleven percent of all purchase orders have only one potential supplier listed. One reason for this is the use of own technology and production capacities, and thereby ignoring possible external suppliers. Another reason is proprietary arrangements in contracts, where it is stated that a certain supplier must be used for a purchase order. A last simple reason is the procurement department did not have any incentives to evaluate more than one supplier, because it was beyond reasonable doubt that this one supplier is the most appropriate supplier.

Next it is analyzed where all potential suppliers of purchase orders for Equipment Materials are located. This data was obtained by counting the number of times a potential supplier was located in a certain country for each purchase order. Note that these are not unique suppliers, as a single supplier can be a potential candidate for multiple purchase orders. An analysis of unique suppliers is also done in this this Sub-Section (see Figure 19).

The results are shown for non-unique suppliers in a pie graph (Figure 18), with a total of 19 countries. It immediately becomes evident that there is a strong bias towards selecting potential suppliers located in the Netherlands (30%) as well as in Germany (24%). Italy and Japan also represent a substantial amount of potential suppliers. Less than 25% of all potential suppliers are located in other countries, which comprise of 17 different countries. Over 75% of all potential suppliers for equipment materials are situated in Europe, 16% are situated in Asia, concluding that less than 10% of all suppliers are located on continents other than Eurasia.

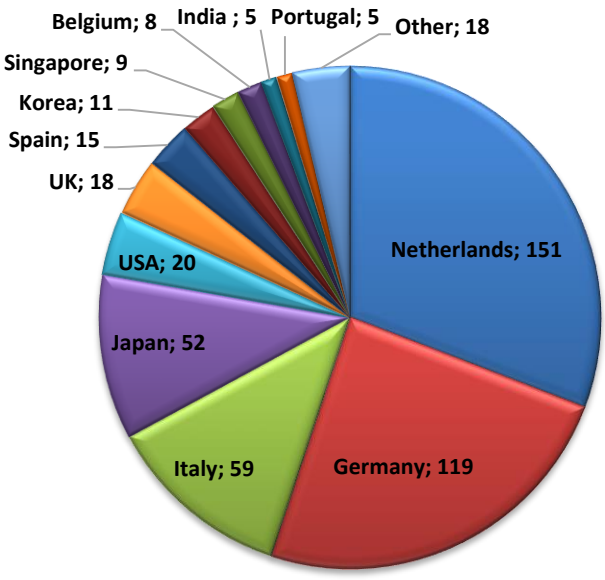

Figure 18: Number of Potential Suppliers per Country for Equipment Materials

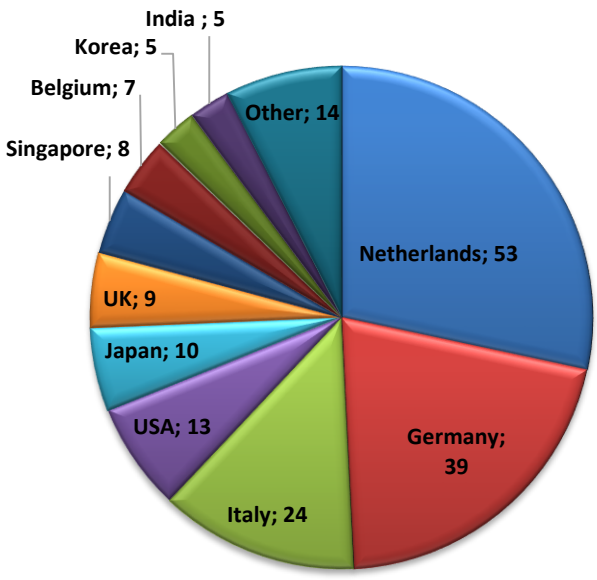

Figure 19: Number of Unique Potential Suppliers per Country for Equipment Materials

To obtain all potential unique suppliers, and the frequency in which they are located in a certain country, the potential suppliers that appeared double in the data sheet are filtered out. In this way the

number of unique potential suppliers in each country are obtained. The total number of unique suppliers is 187, which is a substantial difference compared to the total number of potential suppliers of 490. On average 1 supplier can account for 2.6 purchase orders. There are no large differences in the relative distribution among countries between potential suppliers and unique suppliers, except for Japan. Japan has a relatively small number of unique suppliers (10) compared to the number of purchase orders they could commit to (52). This could indicate economies of scope in Japan, which are defined as an industry that is able to offer a wide variety of products.

3.3.2 ELECTRICAL MATERIALS

The data set of electrical materials contained a total of 17 purchase orders. There are 6 purchase orders for switchgears & transformers, and 6 for cables. The remainders belong in the category 'others'. The total number of (non-unique) potential suppliers in this data sheet is 105. The frequencies for each sub-category, defined by the number of potential suppliers that occur per purchase order, are shown in Figure 20. It immediately becomes evident that there is a mode of 8 suppliers with a frequency of 7. Over 40% of all purchase orders have 8 potential suppliers, indicating that the number of alternatives to each supplier is rather stable. Sub-category switchgears & transformers has the largest contribution to this mode. However it is apparently not necessary to select more than 8 potential suppliers per purchase order for electrical materials. The average will therefore always be lower than the mode; 5.8 potential suppliers per purchase order, which is 1.6 higher than the average of potential suppliers per purchase order of equipment materials. The average potential suppliers per purchase order is higher for switchgears & transformers (7.7) then for cables (6). There are no purchase orders with less than 2 selected potential suppliers.

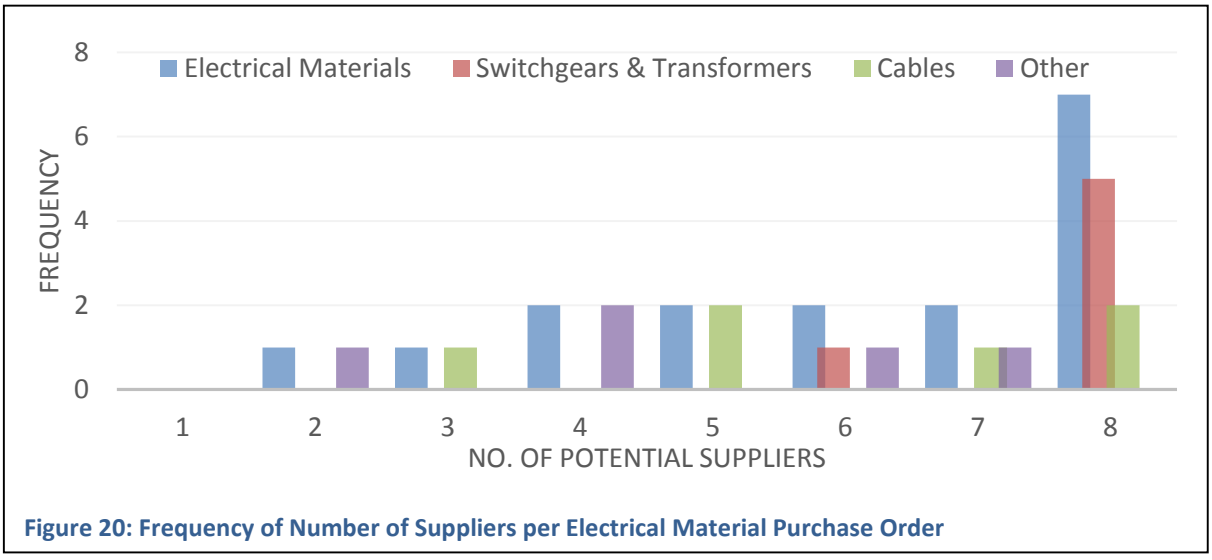

Figure 20: Frequency of Number of Suppliers per Electrical Material Purchase Order

The distribution of potential suppliers for purchase orders among countries is shown in Figure 21, with a total of 12 countries. It shows a similar distribution as described in the analysis of equipment materials. Again, there is a strong bias towards selecting potential suppliers in the Netherlands, which is by far the largest potential supplying country. It represents 31% of the total. There is also a strong bias towards Germany, which takes 21% of the total potential suppliers on its account. Japan represents a substantial part of potential suppliers (15%), followed by the UK (10%) and France (8%). Europe (77%) and Asia (19%) share the majority of the potential suppliers for electrical materials. Italy is however not a strong player in the field of electrical materials (3%), when compared to its share in equipment materials (12%).

The number of unique potential suppliers per country is shown in Figure 22, where all suppliers that appeared double in the data sheet are filtered out. A data set is obtained of 55 unique suppliers,

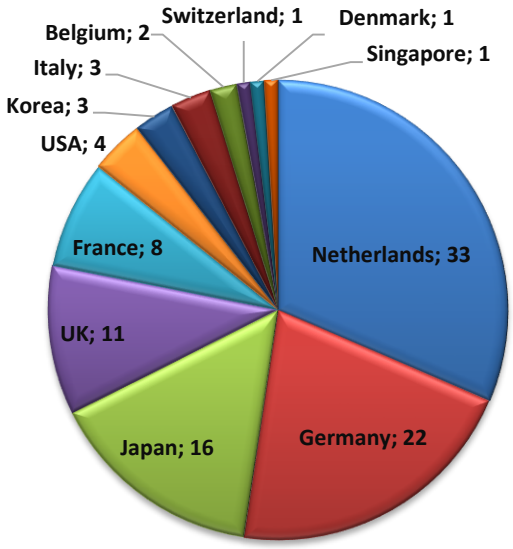

Figure 21: Number of Potential Suppliers per Country for Electrical Materials

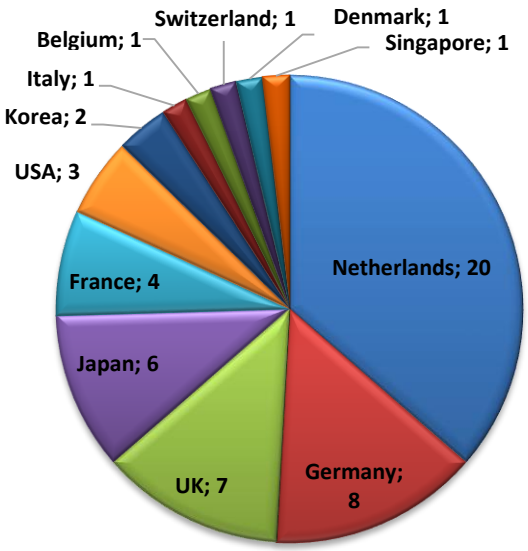

Figure 22: Number of Unique Potential Suppliers per Country for Electrical Materials

indicating that on average one supplier can account for 1.9 purchase order, substantially lower when compared to equipment materials (2.6). The distribution of suppliers among countries is very similar when comparing non-unique suppliers and unique suppliers. The largest difference is seen for Japan, this was also the case for equipment materials. Japan has a relatively small number of unique suppliers (6) versus its number of potential suppliers (16). Again, this illustrates that Japan is achieving economies is scope. Germany also has a relatively small number of unique suppliers (8) that can commit to a large number of purchase orders (22).

3.3.3 INSTRUMENT MATERIALS

Next the data sheet of instrument materials is analyzed. It has a total of 22 purchase orders. Metering & analyzers accounts for 8, and instrument valves for 6 of these purchase orders. The frequencies at which a certain number of potential suppliers is selected for each purchase order are shown in Figure 23. The sub-categories are also shown in this figure. A total of 102 (non-unique) potential suppliers are listed in the data sheet. The mode is quite clear, where 6 purchase orders have 5 potential suppliers. Sub-categories metering & analyzers and instrument valves have an equal contribution to this mode. In relative terms, 27% of all purchase orders of instrument materials have 5 suppliers, which is close to the average number of suppliers per purchase order for instrument materials (4.6). This is also shown graphically, where a quasi-Gaussian distribution is recognizable around the mode, if single source purchase orders are ignored. The average number of potential suppliers per purchase order is larger for metering & analyzers (5.4) than for instrument valves (4.8). There are 2 purchase orders with only 1 supplier due to proprietary arrangements in contracts, and one due to an 'unknown' supplier of miscellaneous materials.

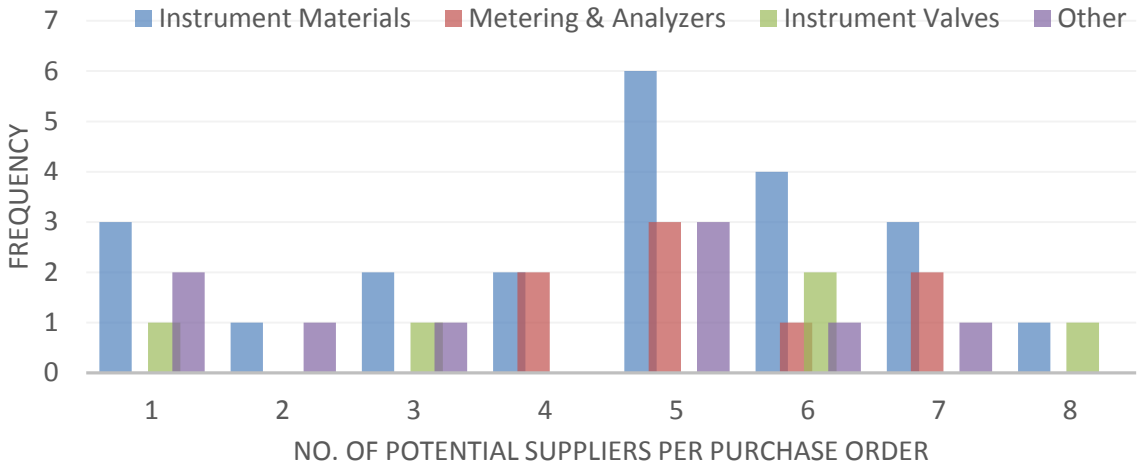

Figure 23: Frequency of Number of Suppliers per Instrument Material Purchase Order

The distribution of (not unique) potential suppliers among different countries for instrument materials is shown in Figure 24, which comprises of 12 countries. As was the case with the other purchase order categories, by far the largest number of potential suppliers is situated in the Netherlands, representing up to 42% of the total. This strong bias is also seen in the selection number of German suppliers, which represent 26% of the total. When combining these two large potential supplying countries, they represent two thirds of all suppliers. This is a substantially larger share than the previous two categories. However, the general distribution of all countries is similar to electrical materials and equipment materials categories. Japan and the UK have a substantial share of the total number of potential suppliers. Italy has a very small share (1%), especially when compared to the large share Italy had in equipment materials (12%).

To show the number of unique suppliers per country, the suppliers that appeared more than once in the data sheet are removed. The outcome is shown in Figure 25. There are 59 unique suppliers, located

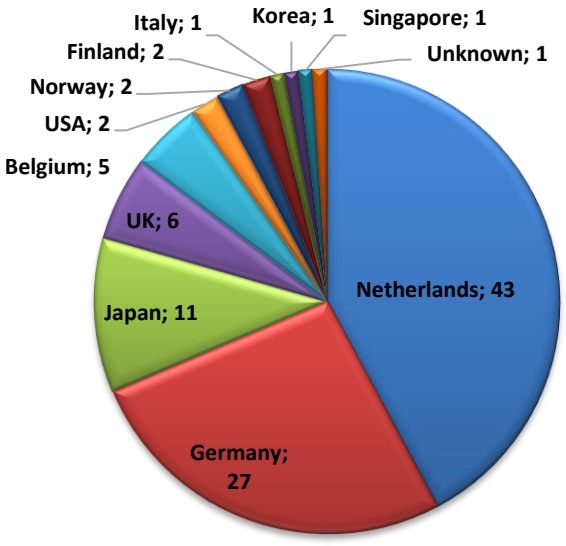

Figure 24: Number of Potential Suppliers per Country for Instrument Materials

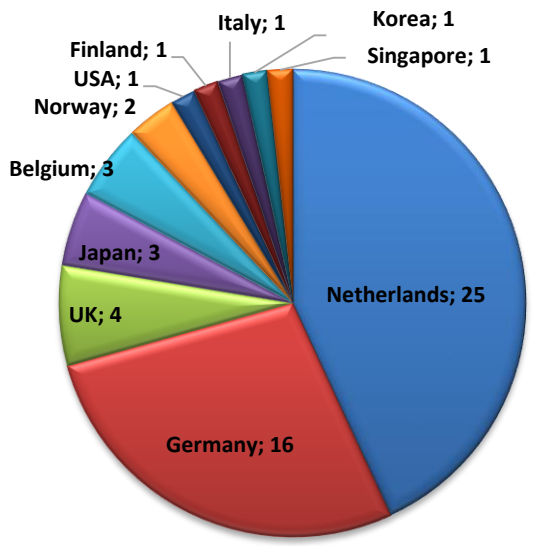

Figure 25: Number of Unique Potential Suppliers per Country for Instrument Materials

in 12 different countries. Dividing the total number of suppliers by the number of unique suppliers shows that, on average, one supplier can commit to 1.7 purchase orders. This is the lowest value of all purchase order categories. The distribution is similar to the total number of potential suppliers shown in Figure 24. The only significant difference is, as was seen with previous categories, Japan. With only 3 unique suppliers, this country can commit to 11 purchase orders. Again, this illustrates Japan is achieving economies of scope.

3.3.4 PIPING MATERIALS

The last purchase order category to be analyzed is piping materials. A data sheet is used with a total of 106 purchase orders. There are a total of 40 purchase orders for bore fittings & pipes and 19 purchase orders for valves. The frequencies of the number of selected potential suppliers per purchase order are shown in Figure 26. A substantial amount of purchase orders (47) can be contributed to category 'others'. Of all data sheets, this one has the largest number of total potential suppliers (765). The mode is, like it is for electrical Materials, on the largest number of suppliers (11) with a frequency of 21. This mode represents 20% of all purchase orders for piping materials, but can be contributed entirely on sub-category bore fittings & pipes. As the mode is on the largest number of potential suppliers, its average must be lower than the mode. This average has the highest value of all purchase order categories (5.8). This average is substantially lower than the average for sub-categories bore fittings & pipes (10.4) and for valves (7.7). Surprisingly there are no purchase orders with 9 suppliers, where there is an abundance of purchase orders with 8 or 10 suppliers. A closer look at the data revealed a standard set of potential suppliers for Valves (8), Pipes (10) or Flanges (11). There are 5 purchase orders with only 1 supplier, where the procurement department apparently did not have incentives to select more potential suppliers (there are certainly more potential suppliers for these purchase orders). All these single source purchase orders are in sub-category 'other'.

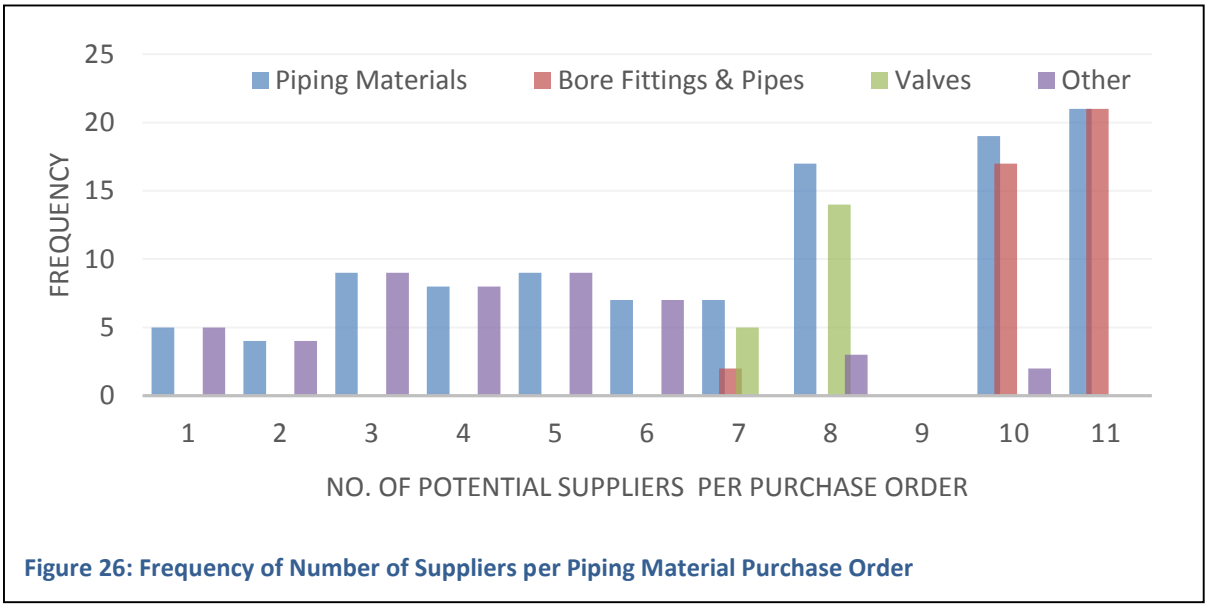

Figure 26: Frequency of Number of Suppliers per Piping Material Purchase Order

The countries and frequencies, where the potential suppliers of piping materials are located, are shown in Figure 27, which comprises a total of 11 countries. Again a distribution is seen where the Netherlands has the largest share of potential suppliers, 42%. The 2nd largest share (25%) can be contributed to Germany. The share of the 2 largest countries is very comparable to the distribution found for electric materials, again representing two thirds of the total. Italian potential suppliers have

a significant share of 15%. Japan, which was large player in all other purchase order categories, has the smallest share of potential suppliers of all countries.

The number of unique suppliers (where all double occurring suppliers are neglected) per country are shown in Figure 28. It shows a total of 80 unique suppliers. On average one supplier can commit to 9.6 purchase orders. This is by far the largest value of all purchase order categories, where the 2nd largest

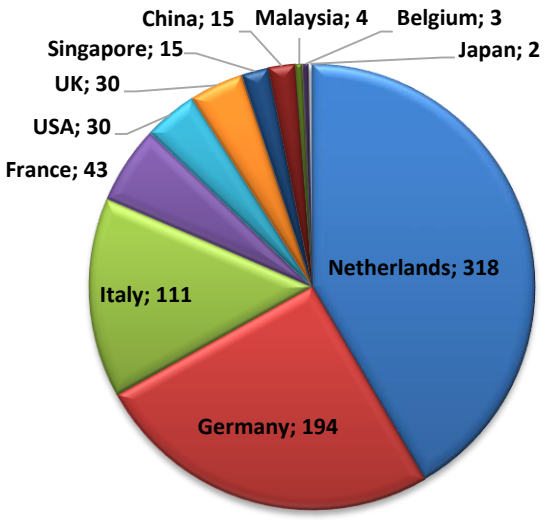

Figure 27: Number of Potential Suppliers per Country for Piping Materials

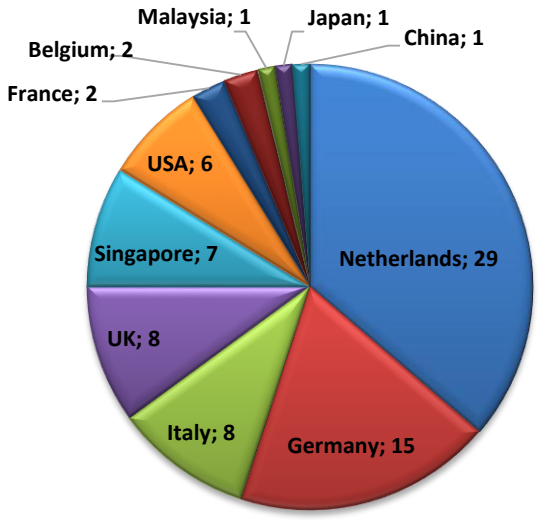

Figure 28: Number of Unique Potential Suppliers per Country for Piping Materials

value is 2.6. The distribution looks a bit similar to the distribution that shows all 'non-unique suppliers', when looking at the 3 largest suppliers. One extreme seems China; with only 1 supplier it can commit to 15 purchase orders. When looking closer at the data, there are 8 suppliers that can commit to over 40 purchase orders. All these suppliers are located in the Netherlands, Germany, Italy or France.

3.3.5 OVERAL POTENTIAL SUPPLIERS OF PURCHASE ORDERS

Next an analysis is done on the overall potential suppliers, all purchase order categories taken together. As was done with the previous analyzes, firstly the number of potential supplier and its frequencies, are discussed (Figure 29). There is a total of 262 purchase orders. For these purchase orders there are 1462 potential suppliers. This is an average 5.6 potential suppliers per purchase order. The distribution can be seen as quasi-Gaussian, with its mode (5) near the average (5.6). However, its mode represents only 15% of all purchase orders, which indicates a more uniform distribution. There are a total of 21 purchase orders with only 1 potential supplier (8%). The reasons for single source purchase orders are discussed in the previous analyses': using own production possibilities and proprietary arrangements. Another reason is, for selecting only one potential supplier, when it is beyond reasonable doubt which is the most suitable supplier.

Using excel the data is used to calculate the mean frequency (23.8) and the standard deviation (10.9) of the data set. With the mean and standard deviation a data set was randomly generated (total 20,000 data points) using the 'Random Number Generation' tool in excel. This data could be plotted using the 'Histogram' function in the Data Analysis options of excel, as shown with the red line in APPENDIX C.

It is adjusted to fit the range of potential suppliers per purchase orders found in the analysis of this Section (1-11 potential suppliers). Furthermore the randomly generated data is adjusted in a way that the sum product of potential suppliers and its corresponding frequencies would add up to the total number of potential suppliers (1462). The curve has its optimum at 6, as it is the nearest integer rounding of the average of 5.6 potential suppliers per purchase order.

The normal distribution curve (APPENDIX C) does not fit well to the actual data, therefore a normal distribution of number of selected potential suppliers is rejected.

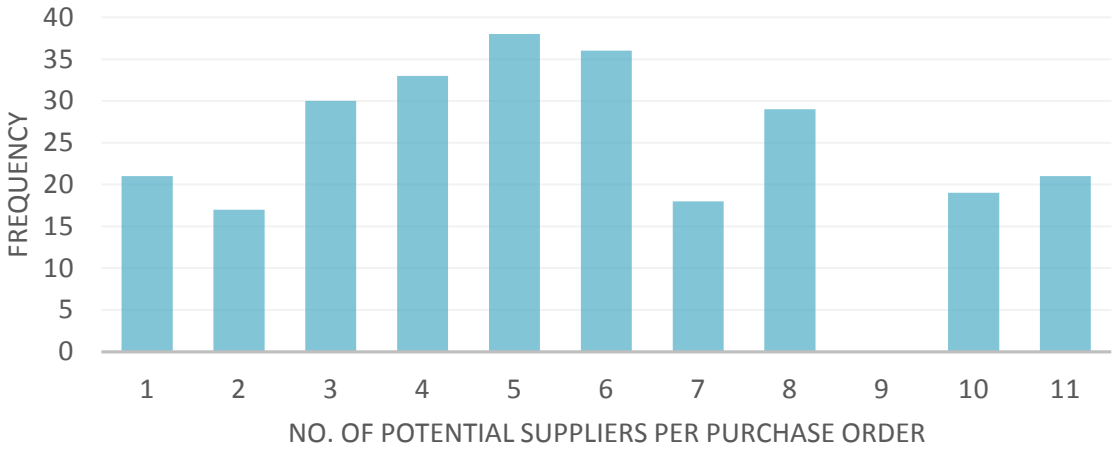

Figure 29: Frequency of Number of Suppliers for all Purchase Orders

In Figure 30 (large supplying countries) and Figure 31 (small supplying countries) the distribution is shown of the potential suppliers and the countries they are located in. A separation between small and large countries is done for the sake of clarity and completeness. In total there are 24 possible sourcing countries. As was seen in the analyses' of each purchase order category, the country with the largest share of potential suppliers is the Netherlands (37%) followed by Germany (25%). Italy (12%)

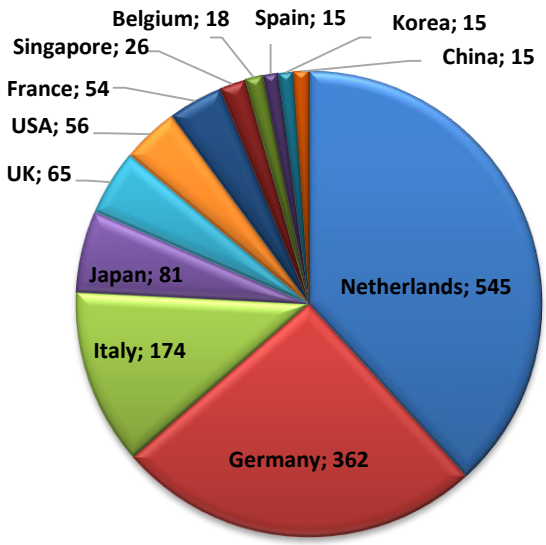

Figure 30: Large numbers of Potential Suppliers per Country for all Purchase Order Categories

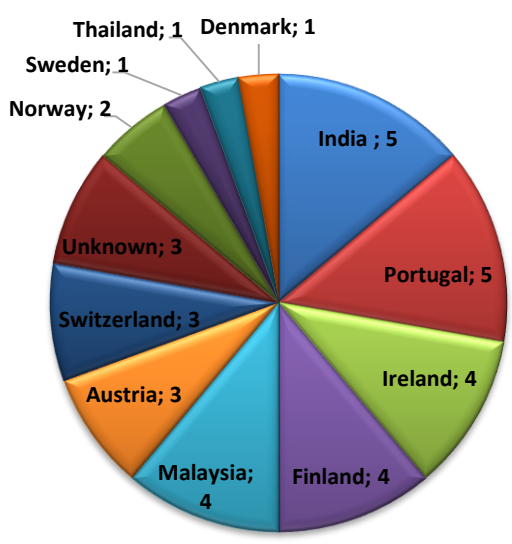

Figure 31: Small Numbers of Potential Suppliers per Country for all Purchase Order Categories

and Japan (6%) also have a significant share in the number of potential suppliers. All other countries have a share of potential suppliers smaller than 5%. As the data sheets of equipment materials and piping materials are significantly larger than those of electrical and instrument materials, these overall results are a bit biased. Nevertheless the distribution of each category is more or less similar, especially when comparing the countries with large numbers of potential suppliers.

Figure 32 illustrates, for all purchase order categories, the number of unique potential suppliers for each country. In total there are 368 unique potential suppliers, not a huge difference comparing the summation of all unique suppliers of all categories (381). This indicates that only a few suppliers are active in multiple purchase order categories. On average 1 supplier can commit to 4.0 purchase orders. This value is highly biased due to piping materials (see Sub-Section 3.3.4). The share of the Netherlands plus Germany has declined from 62% to 52%, a substantial decrease. No large differences in the distribution of other countries are determined when comparing the unique and non-unique potential suppliers.

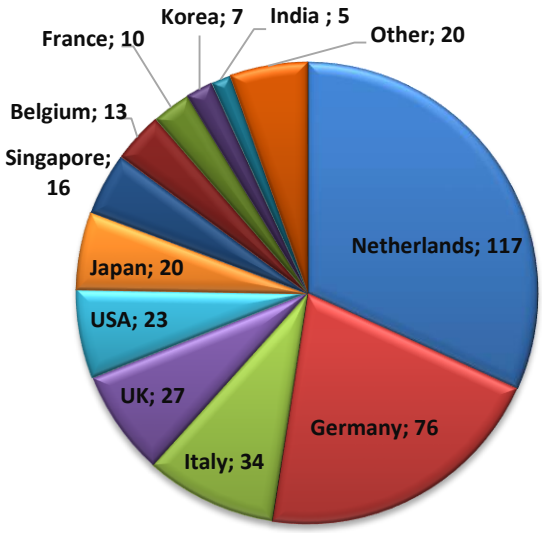

Figure 32: Numbers of Unique Potential Suppliers per Country for all Purchase Order Categories

3.3.6 SUMMARY OF DESCRIPTIVE STATISTICS

This Sub-Section summarizes the findings of this Section. In Table 6 the different purchase order categories are compared, with respect to the number of purchase orders (PO), potential suppliers (PS), unique potential suppliers (UPS), averages, modes, number of unique countries, and the four largest potential sourcing countries.

It immediately becomes evident that the Netherlands is the single largest potential sourcing country for all categories. The second largest is consistently Germany. Italy and Japan are also important players in almost all categories. The UK is a large potential supplier for instrument materials and electrical materials. France has a notable share as a potential supplier of piping materials. Equipment materials has the largest number of unique potential suppliers and number of possible sourcing countries, but the lowest average number of suppliers per purchase order. For other categories the number of sourcing countries does not differ significantly. Piping materials has the highest number of potential suppliers per purchase order (7.3), significantly larger than the NKNK projects average of 5.6. Electrical materials also has more than average suppliers per purchase order. However, this difference is only minor.

A total of 24 potential supplying countries indicates the wide variety of sourcing possibilities, but it must be noted that 12 of these countries can only be a potential supplier for up to 5 purchase orders per country. In total, this half of the total number of possible countries can only account for 14% of all

Table 6: Summary of Descriptive Statistics on Potential Suppliers

Category	PO, PS, UPS	Average, Mode	No. of Countries	4 Largest Countries
Equipment Materials	PO 117 PS 490 UPS 187	Average 4.2 Mode 6	19	Netherlands 31% Germany 24% Italy 12% Japan 10%
Electrical Materials	PO 17 PS 105 UPS 55	Average 5.8 Mode 8	12	Netherlands 31% Germany 21% Japan 15% UK 10%
Instrument Materials	PO 22 PS 102 UPS 55	Average 4.6 Mode 5	12	Netherlands 42% Germany 26% Japan 11% UK 6%
Piping Materials	PO 106 PS 765 UPS 80	Average 7.3 Mode 11	11	Netherlands 42% Germany 25% Italy 14% France 6%
Overall Categories	PO 262 PS 1462 UPS 368	Average 5.6 Mode 5	24	Netherlands 38% Germany 25% Italy 12% Japan 6%

purchase orders. Equipment materials have the highest diversity in terms of possible sourcing countries. The other categories have more or less an equal amount of potential sourcing countries. There are 21 purchase orders with only 1 suitable supplier, caused by CB&I's preference of using own production possibilities and proprietary arrangements. There are often standard lists of potential suppliers for specific types of purchase orders, based in experience with previous projects.

3.4 CORRELATION OF DEGREE OF COMPETITION AND SELECTED POTENTIAL SUPPLIERS

In this Section it is tried to derive a correlation between the results of the questionnaires of Chapter 2 and the descriptive statistics in Section 3.3. Firstly, all data used in order to derive a correlation is summarized in Table 7. Note that sub-category cables has 2 modes. Secondly, propositions are stated, on the possible correlations between the outcome of the questionnaires and the descriptive statistics on the potential suppliers for purchase orders. Thirdly, these propositions are tested to determine, which proposition best fits the data. In addition its statistical significance is determined, using P-Values. The possible implication of this correlation is to determine beforehand, based on a just a questionnaire, the number of potential suppliers that will be selected for a project. The perceived competition is part of the project context. Therefore, if the perceived competition has large effects on the selection of suppliers, this has to be taken into account for estimating potential suppliers in future similar projects.

Table 7: Summary to compare outcome Questionnaires and Descriptive Statistics

Category	Sub-Category	Questionnaires		Descriptive Statistics	
		Averages (Supply)	Averages (Demand)	Average No. of Suppliers per Purchase Order	Mode of Suppliers per Purchase Order
Equipment Materials	Static Equipment	3.2	4.0	4,5	6
	Rotating Equipment	4.0	3.4	4,0	5
Electrical Materials	Cables	4.7	1.9	6	5 & 8
	Switchgears&Transf.	3	2.0	7,7	8
Instrument Materials	Metering & Analyzers	4.0	3.5	5,4	5
	Instrument Valves	4.0	3.3	4,8	6
Piping Materials	Bore Fittings & Pipes	3.7	2.2	10,4	11
	Valves	3.7	2.2	7,7	8

It is shown in Chapter 2 that there is imperfect competition in all purchase order categories. However, the extent to which there is imperfect competition differs per purchase order category. Section 3.1 points out that there are restrictions to the amount of suppliers that can be selected per purchase order, due to the Approved Vendor List. It is also important to note, when an inquiry is sent to a supplier, this will not always result in a bid. Suppliers may not offer a bid in case they are reaching capacity constraints, because they simply do not have the resources to prepare a bid. Therefore, when there is high demand in the market, one is less likely to receive a bid from each supplier selected. This provides an argument for procurement managers to select a larger set of potential suppliers, in order to get a reasonably well bid.

3.4.1 SUPPLY SIDE COMPETITION

Proposition 1: *The degree of perceived competition on the supply side is positively correlated to the number of selected potential suppliers.*

The reasoning behind this proposition is the following. If there is a higher degree of perceived competition on the supply side in a purchase order category, there probably is a higher than average number of suppliers on the approved vendor list. This is reflected by the number of potential suppliers that are selected for a project.

It is tested whether there is a linear correlation between the average scores of the questionnaires on the supply side per category, and the average number of potential suppliers. This correlation is also tested for the mode of potential suppliers. The available data of all sub-categories is used, and a simple linear regression line is calculated using the 'Trendline' function in an Excel 'Scatter Plot'.

It was tested whether these results are significant, using the 'data analysis' tool in excel for regression. It gives corresponding P-values for the constant of the regression line (i.e. the interception with the y-axis) and the slope of the line. P-values are an important measure to determine whether the values of the constant and the slope are not derived by chance. A low P-Value indicates a high probability that the estimated values are correct, where high P-values indicate a less significant result. A P-value lower

0.05 is traditionally used to reject a null hypothesis (Fischer, 1925), rejecting that there is no relationship between two phenomena. In this thesis a proposition will be rejected, when its corresponding P-value is higher than 0.05.

The 'goodness of fit', the degree on which the line fits the data, is calculated for the trend line. This coefficient of determination is denoted as R^2. R Squared ranges from zero to one, where '0' indicates no fit between linear regression line and data and '1' indicates a perfect fit between linear regression line and data. This process is completed for both the average and the mode of potential suppliers for all sub-categories. The correlations of average and mode are shown in Figure 33. Note that in this graph, a low average score in the questionnaires indicates a high value of perceived competition on the supply side.

Both regression lines are downward sloping, meaning that the more competitive the supply side of an industry is, the more potential suppliers are selected. This supports proposition one. It was tested whether this result is significant. R squared indicates for both the average (0.05) and the mode (0.08) that the fit is not very convincing. The fact that the lines are only slightly downward sloping with, low corresponding values for R squared, indicate that this data does not strongly support proposition 1. The P-Values for the slopes are 0.595 for the average regression line and 0.485 for the mode regression line.

As both P-values are above 0.05 proposition 1 is rejected for the average and the mode.

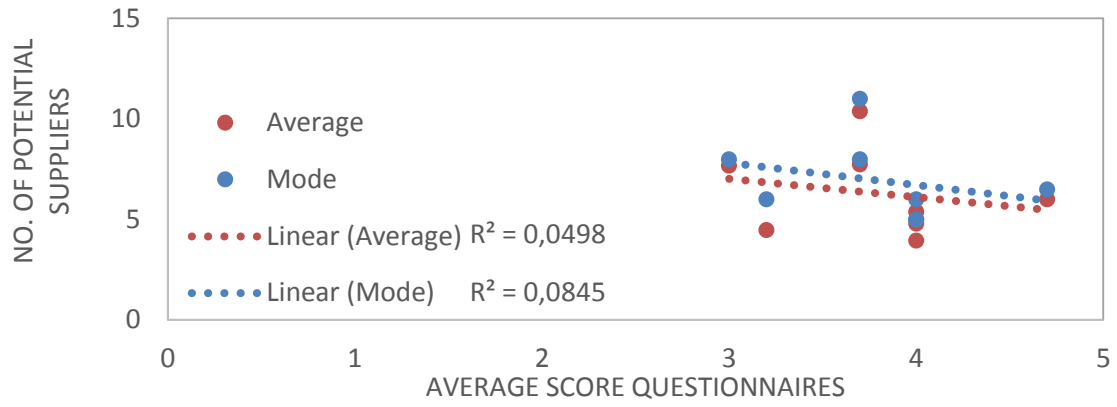

Figure 33: Linear Correlation Supply Side Questionnaires and Average/Mode

Equation for Average: y = -0.9119x + 9.7516 **Equation for Mode: y = -1.1065x + 11,128**

3.4.2 DEMAND SIDE COMPETITION

Proposition 2: *The degree of perceived competition on the demand side is positively correlated to the number of selected potential suppliers.*

The reasoning behind this proposition is the following. When a high degree of competition is perceived among buyers, these buyers compete with each other for suppliers. This is reflected by suppliers not respsonding to all inquiries received, due to the lack of resources. Suppliers reaching capacity constraints may also be tempted to offer abnormally high bids. The more potential suppliers are selected, the less chance buyers have to compete among the same supplier. This makes it more likely

that a reasonable large set of bids will be received. Thereby a buyer will be able to minimize sourcing cost.

It is tested whether there is a linear correlation between the average scores of the questionnaires on the demand side per category, and the average number of potential suppliers. This correlation is also tested for the mode of potential suppliers. The available data of all sub-categories is used, and a linear regression line is calculated using the 'Trendline' function in an Excel 'Scatter Plot'.

The 'goodness of fit', the degree on which the line fits the data, is calculated for the trend line. This coefficient of determination is denoted as R^2. R Squared ranges from zero to one, where '0' indicates no fit between linear regression line and data and '1' indicates a perfect fit between linear regression line and data.

Using the 'data analysis' tool in excel for regression P-values are calculated to determine whether the result is significant. With a P-value for the slope above 0.05 the proposition is rejected. This process is completed for both the average and the mode of potential suppliers for all sub-categories. The correlation of average and mode are shown in Figure 34. Note that in this graph, a low average score in the questionnaires indicates a high value of perceived competition on the demand side.

The regression lines look somewhat similar then the results on the supply side. Both lines in Figure 34 are downward sloping, meaning that the more competitive the buyers' market is perceived, the more suppliers there are selected per purchase order. This supports proposition 2. For both the average (0.54) and the mode (0.44) the goodness of fit, or R squared, is reasonably well compared to the previous analysis on the supply side competition. The slope for the average number of potential suppliers in the linear correlation line on the demand side, is twice as steep as seen for the supply side. This indicates a stronger relationship between questionnaires and average number of potential suppliers compared to the supply side analysis. The P-value for the slope of the average is 0.037, indicating that the correlation is significant. The P-Value for the mode is 0.073, indicating that the correlation is not significant.

Proposition 2 is not rejected for the average. Proposition 2 is rejected for the mode.

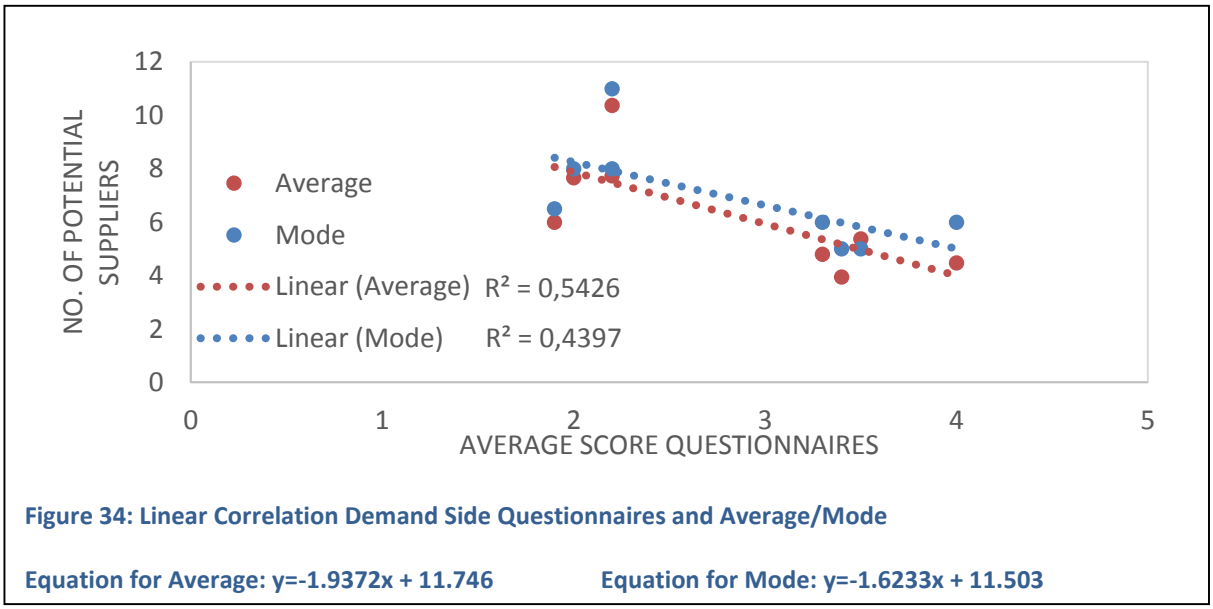

Figure 34: Linear Correlation Demand Side Questionnaires and Average/Mode

Equation for Average: y=-1.9372x + 11.746 **Equation for Mode: y=-1.6233x + 11.503**

3.4.3 RELATIVE DIFFERENCE SUPPLY & DEMAND SIDE COMPETITION

Proposition 3: *The relative difference between perceived competitions is positively correlated to the number of selected potential suppliers.*

Where relative difference is calculated as shown in equation (2); C is perceived competition.

$$Relative\ Difference(\%) = \frac{C_{supply} - C_{Demand}}{C_{supply}} \cdot 100\% \quad (2)$$

The reasoning behind this is; the stronger the bargaining power of suppliers over buyers, the more suppliers have to be evaluated by buyers in order to receive a reasonable bid. Put differently, the more bargaining power buyers have over suppliers, the less incentives buyers have to evaluate high number of suppliers, as suppliers engage in Bertrand competition in order to win the contract.

It is tested whether there is a linear correlation between the relative difference on the supply and demand side (Equation (2)) of the questionnaires per category, and the average number of potential suppliers per category. This correlation is also tested for the mode of potential suppliers. The available data of all sub-categories is used, and a linear regression line is calculated using the 'Trendline' function in an Excel 'Scatter Plot'.

Using the 'data analysis' tool in excel for regression P-values are calculated to determine whether the result is significant. With a P-value for the slope above 0.05 the proposition is rejected. The 'goodness of fit', the degree on which the line fits the data, is calculated for the trend line. This coefficient of determination is denoted as R^2. R Squared ranges from zero to one, where '0' indicates no fit between linear regression line and data and '1' indicates a perfect fit between linear regression line and data. This process is completed for both the average and the mode of potential suppliers of all sub categories. The correlations of average and mode are shown in Figure 35.

The regression lines of the average and the mode look very similar. The fact that they are upward sloping indicate that: the larger the difference between the perceived competition on the supply and demand side the more suppliers are selected. This is in accordance with proposition 3. As the relative

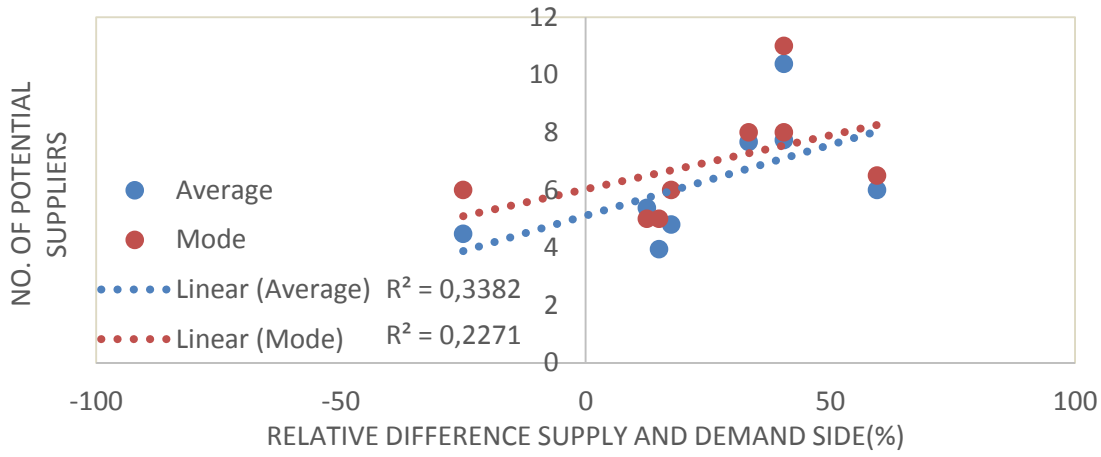

Figure 35: Linear correlation Relative Difference Supply/ Demand perceptions & Average/Mode

Equation Average: y = 0.0526x + 4.9895 **Equation Mode: y = 0.0407x + 5.9257**

difference is calculated by subtracting competition on the demand side from competition on the supply side, a negative value occurs when buyers have more bargaining power than suppliers. This occurs only with static equipment, seen on the left hand side of the y-axis. R squared has a lower value for the mode (0.23), than for the average (0.33), but both are quite low. As the lines are scaled relative to the competition on the supply side, no comparison can be made on the steepness of the curve with the other two propositions. The P-Values for the slopes are 0.131 for the average and 0.233 for the mode, indicating that both correlations are not significant.

Therefore Proposition 3 is rejected for both the average and the mode.

3.4.4 SUM OF SUPPLY AND DEMAND SIDE COMPETITION

The goodness of fit of all regression lines indicate that the perception of competition on the supply and demand side is not a very good indicator for the number of suppliers that are selected for each purchase order category. Most of the tested propositions are not significant and therefore all propositions are rejected, besides proposition 2 for the average number of potential suppliers. As in general more competition (on the supply and the demand side) lead to a larger number of potential suppliers selected per purchase order, one can sum op the values of the perceptions of the supply side and the demand side, to obtain a total level of competition. A final proposition will be tested:

Proposition 4: *A high degree of competition on the supply and the demand side is positively correlated to the number of selected suppliers.*

Using a linear regression technique on this data (Figure 36), a downward sloping regression line is seen. This correlation is negative, because a low sum of averages indicates a high degree of competition on the supply as well as the demand side. This supports proposition 4. The value of R-squared obtained is the highest seen so far, for both the average (0.62) and the mode (0.58). It was tested whether these results are significant, using the 'data analysis' tool in excel for regression. P-Values for the slope are obtained for the average (0.020) and for the mode (0.028). Both P-Values are below 0.05.

Therefore Proposition 4 cannot be rejected for both the average and the mode.

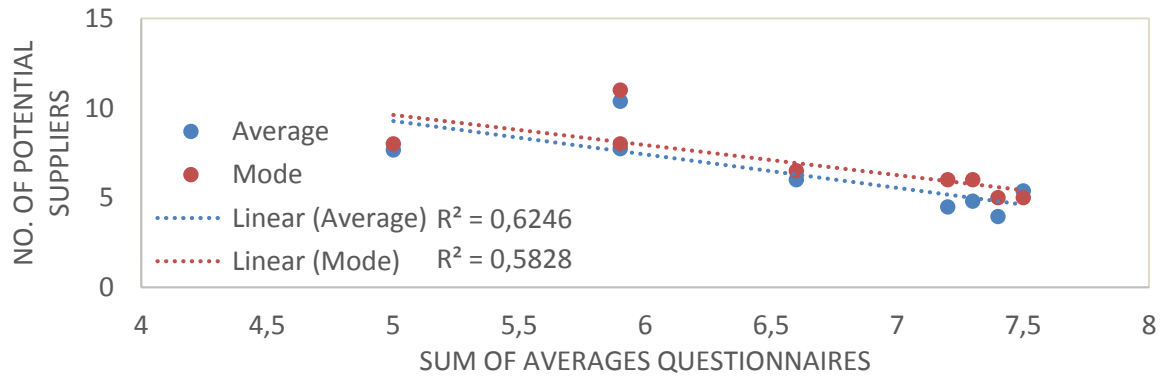

Figure 36: Linear Correlation Sum of Supply & Demand perceptions and Average/Mode

Equation Average: y = -1.6781x + 18.013 **Equation Mode: y = -1.8663x + 18.615**

3.4.5 CONCLUSIONS

In this Section it is shown that a high degree of perceived competition lead to a larger selection of potential suppliers. This is the case for competition on the supply- as well as the demand side, which is shown through a simple linear regression analysis. Four propositions are stated, which are tested whether there are in accordance with the linear regression analysis, by determining the slope and the corresponding goodness of fit. It was also tested whether the results are significant, by determining the P-Value of the regression lines. Although the results seemed to support all propositions, only proposition 2 and 4 were not rejected on a significance level of 0.05. The most convincing proposition is proposition 4, 'a high degree of competition on the supply and the demand side is positively correlated to the number of selected suppliers', as it was not rejected for both the average and the mode. With this correlation the amount of selected suppliers for a project could be estimated on the basis of some questionnaires. The perceived competition is part of project context, therefore it complements on the impact of project context on the number of selected suppliers. In the next section a project similar to the NKNK project is analyzed, and the importance of project context is underpinned in more perspectives.

3.5 DESCRIPTIVE STATISTICS ACTUAL SOURCING COUNTRIES ECC PROJECT

In this Section descriptive statistics is shown on the potential suppliers of the reference (ECC) project. In addition it is determined, where purchase order were eventually sourced. The data obtained for this analysis is slightly different than what was used to collect the data on descriptive statistics of potential NKNK suppliers in Section 3.3. Data is used in this Section of the reference project ECC which is obtained from the internal CB&I database, instead of excel sheets provided by procurement managers. Data sheets provided by procurement managers, with purchase orders and potential suppliers for the NKNK project, are significantly different than what was found in the data base for ECC. This is unexpected because both are essentially the same project, only of a slightly different size and location. The excel sheets of the procurement managers were tried to be duplicated. In this way substantial differences in the selection of potential suppliers are explored. Also the database had some missing purchase orders, but also provided some extra purchase orders when comparing NKNK and ECC.

The differences revealed in this Section could reflect the impact of the project context on the selection of suppliers and their countries. The ECC project was executed in Asia and there were no budgetary constraints, as the project owner had sufficient equity. It can thereby source from whatever country it wishes. This is in contrast to the NKNK project, which has ECA related budgetary constraints. There could be a bias in projects towards selecting suppliers in the region for both political, logistic, and financial reasons. It is important to note that once a potential supplier has been allocated to a country, this does not necessarily imply that the equipment is actually manufactured in that country. When it is not yet determined in the bid offerings by the supplier, this is subject to change. A supplier could choose in that case a manufacturing country, which has the desired operating conditions at that moment in time. Things that could influence this choice are capacity constraints, raw material prices and other factors, which are discussed in more detail in Chapter 4.

3.5.1 EQUIPMENT MATERIALS

In this Sub-Section equipment materials are discussed for the ECC project. As both projects are similar, they both have an almost equal amount of purchase orders. For static equipment both ECC and NKNK have 48 purchase orders, for rotating equipment ECC has 49 purchase orders where NKNK has 43 purchase orders. Special equipment shows a large difference when comparing purchase orders of both projects; 43 for ECC and 26 for NKNK. Bids were found for 117 of a total of 138 purchase orders. The amount of potential suppliers for the ECC project is 471, compared to 490 for the NKNK project. This is not a huge difference in total amount. It is shown there is a huge difference in the distribution of potential suppliers among different countries for purchase orders, when comparing selected potential suppliers of the ECC (Figure 37) and NKNK project. Korea was the largest potential supplier for the ECC

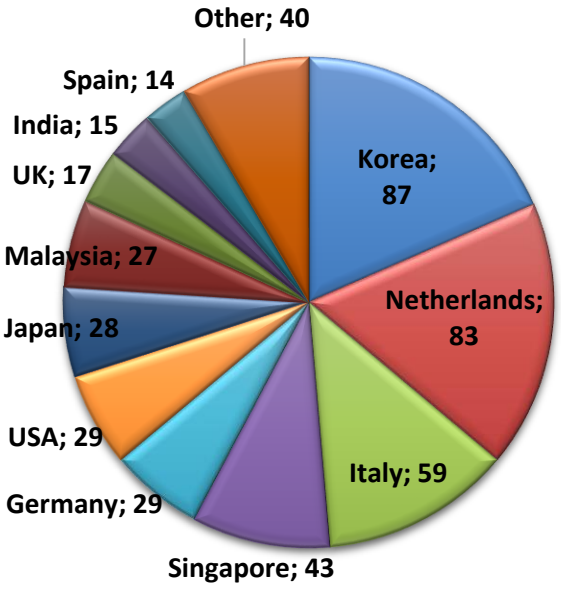

Figure 37: Potential Suppliers Equipment Materials ECC

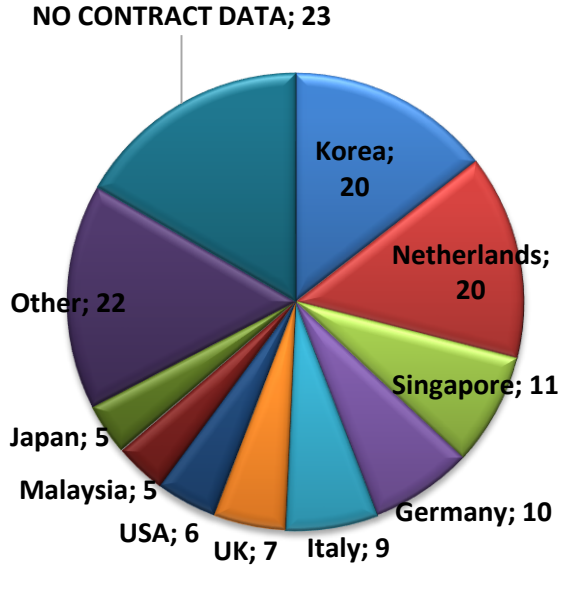

Figure 38: Actual Supplier Equipment materials ECC

project, where it is not a dominant player in the NKNK project. For the NKNK project the Netherlands and Germany are dominant players, where only the Netherlands is also a dominant player in the ECC project. It is also seen that a lot of equipment materials can be sourced in Singapore, the country where the plant is to be established. This is in contrast to the NKNK project.

The question now to be asked is where the actual sourcing came from in the ECC project. This is shown in Figure 38. Korea and the Netherlands are the largest players in the field for equipment materials. They both were as potential suppliers, and they both are as actual suppliers. The relative size they capture has not changed significantly. There is however a small bias towards selecting the supplier from the country where the project is to be executed; Singapore. Italy was apparently not a very attractive country to source from, as its share has declined significantly. For 23 purchase orders there was no contract data to be found in the database. This could be due to the following reasons.

- Contracts have not been stored in the database due to mistakes.
- Purchase orders have been merged.

- Certain pieces of equipment might not have been necessary anymore.

Germany is an attractive country to source from. Although it is not a very large supplying country it remained its share, when compared to the number of potential suppliers it had for the ECC project.

When analyzing the data, it became evident that there are significant differences among the distributions of actual suppliers, when comparing static en rotating equipment. Special equipment is left out of this analysis, as the nature of these equipment types is ranging from firefighting equipment to flexible conduits, and therefore no generalizations for this subcategory of equipment materials can be made. The distribution of actual suppliers and their countries ,for static equipment and rotating equipment, is shown in Figure 39 and Figure 40. For static equipment contract data was found for 43 of the 48 purrchase orders. Releatively more purchase orders with no contract data are seen with rotating equipment: nine purchase orders with no contract data at a total of 49 purchase orders.

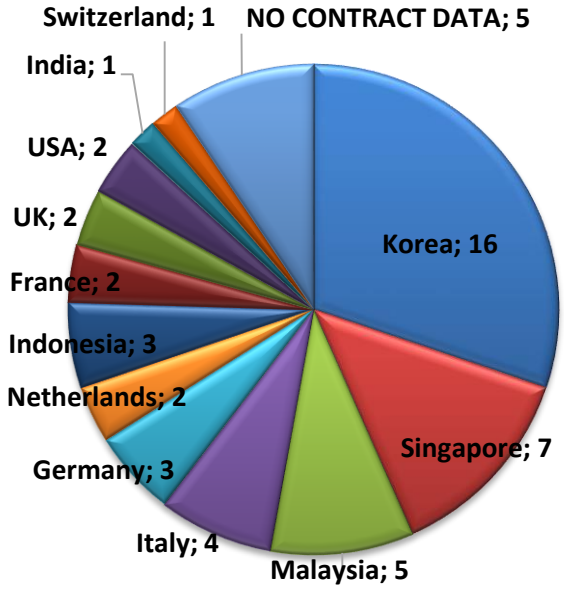

Figure 39 Actual Suppliers Static Equipment ECC

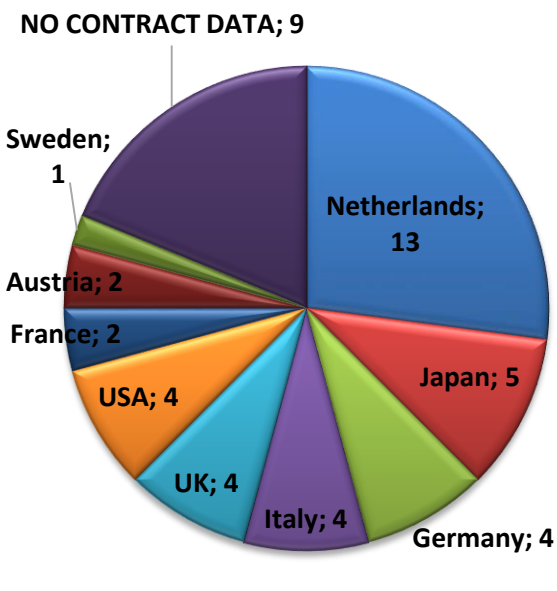

Figure 40: Actual Suppliers Rotating Equipment ECC

When comparing sub-categories static and rotating equipment it becomes evident that Korea had been the most attractive potential supplier for static equipment in the ECC project. It supplied over 25% of all static equipment. For rotating equipment Korea was not suitable. Korea had even not been listed as a potential supplier of rotating equipment. It can be stated, on the basis of this data, that Korea is specialized in the manufacturing of static equipment, but is certainly not a preferred supplier for all equipment materials. The country in which the project is executed, Singapore, and its neighboring country Malaysia are the 2nd and 3rd largest suppliers of static equipment. This could indicate the importance of the geographical location of suppliers for static equipment, in determining where to source from. Italy and Germany represent a respectable part of sourcing for both static and rotating equipment. The Netherlands is a leading supplier for rotating equipment, representing over 25% of all sourcing for rotating equipment. However, it supplies only a minor part of static equipment. The 2nd largest supplier for rotating equipment is Japan, which was in its turn not a supplier of static equipment.

3.5.2 ELECTRICAL MATERIALS

For electrical materials the number of purchase orders differs significantly when comparing the ECC (32 purchase orders) and the NKNK project (17 purchase orders). This is mainly due to the pooling of purchase orders for the NKNK project, to 'make life easier'. For example, ECC had a purchase order for 'low voltage cables' and 'low voltage cables accessories', where NKNK has these purchase orders pooled into a single purchase order; 'low voltage cables'. For 21 purchase orders bids were found. The number of total potential suppliers does not differ significantly, 106 for ECC and 105 for NKNK. The distribution among countries of potential suppliers for electrical materials is shown in Figure 41. Compared to the NKNK project, the potential share of Dutch suppliers has increased from 31% to 46%. Another important difference is that Germany was not a large potential supplier for the ECC project, where it is the second largest for the NKNK project. The appearance of Singapore as a potential supplier for the ECC project, indicates its geographical importance.

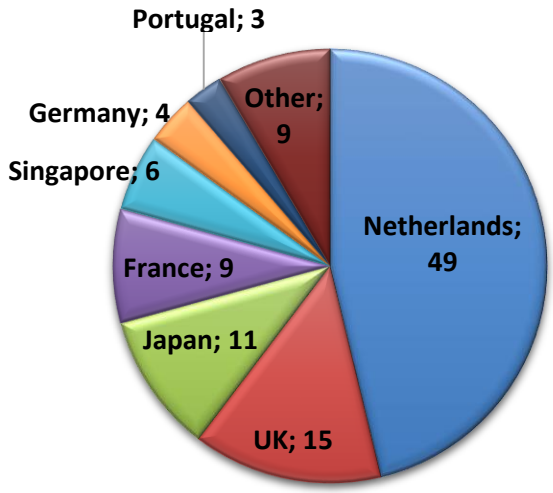

Figure 41: Potential suppliers Electrical Materials ECC

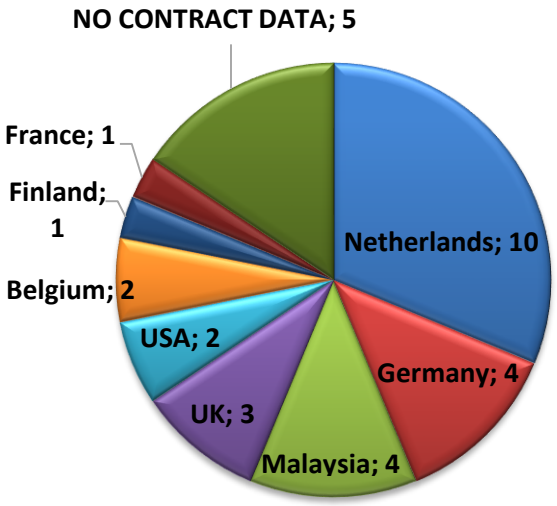

Figure 42: Actual Suppliers Electrical Materials ECC

Where the sourcing actually came from for the ECC project is shown in Figure 42. Contract data was obtained for 27 of the total of 32 purchase orders in this category. 14% is sourced from the Netherlands. Germany was listed as a potential supplier for 4 purchase orders, and is an actual supplier of 4 purchase orders. One might think that all potential suppliers from Germany were used, but this is not the case. As was indicated in the introduction of this Section, allocating a country to a potential supplier does not necessarily imply that the goods are manufactured in that country. For all cases of electrical materials, where the goods are manufactured in Germany according to the contract data, these were listed as suppliers located in a country other than Germany (all were Dutch). A similar story unfolds for Malaysia, which is together with Germany the 2nd largest sourcing country for electrical materials. Only 1 purchase order was supplied by a Malaysia, where Malaysia was also listed as a potential supplier for that purchase order. The other 3 where listed as Dutch suppliers, which also had production facilities in Malaysia. This contributes to the declined share of the Netherlands, which was listed as a large potential supplier, but having a smaller proportion as an actual supplier. According to the data Japan is not an attractive country to source from. It has a proportion of 10% of potential suppliers, but actually supplying nothing for the ECC project for electrical materials. There were 5

purchase orders of which no Contract data is obtained, that is because the country of manufacturing is not known. This could have some impact on the conclusions drawn here.

3.5.3 INSTRUMENT MATERIALS

A total of 82 purchase orders are identified for in ECC project for instrument materials, almost a fourfold when compared to the NKNK project. Again, this is mostly due to the pooling of purchase orders, which is done for the NKNK project. The most striking example for this is 'flow meters', which is a single purchase order for the NKNK project, but has a total of 21 different flow meters, and 21 different purchase orders for the ECC project. Only a total of 28 purchase orders has available potential suppliers for electrical materials. The total number of potential suppliers (65) and their distribution among countries is shown in Figure 43. The Netherlands is the largest potential supplier, representing a total of 65% of all potential suppliers. This is a large difference compared to the NKNK project, where the share of potential suppliers for the Netherland is 42%. More striking though, is the absence of Germany as a potential supplier for the ECC project, where it is the second largest for the NKNK project. The UK is the second largest potential supplier and Singapore again demonstrates the importance of the geographical location for being selected as a potential supplier. Japan was absent in the list of potential suppliers.

The actual suppliers are shown in Figure 44. Note that comparisons with the potential suppliers is not very straightforward, because of the difference between the total amount of purchase orders (82), and the amount of purchase orders where potential suppliers were available (28). No contract data was found for 3 purchase orders. The Netherlands is the largest sourcing country, representing over 25% of all purchase order contracts for instrument materials. A surprising second largest is the USA. This is mainly because of European listed suppliers decided to manufacture their goods in the USA. Germany was listed as a potential supplier of one purchase order, nevertheless over 13% of all purchase orders were manufactured in Germany. This is due to suppliers with their office listed in the Netherlands, decided to manufacture in Germany. The same holds for Japan, where predominantly Dutch suppliers

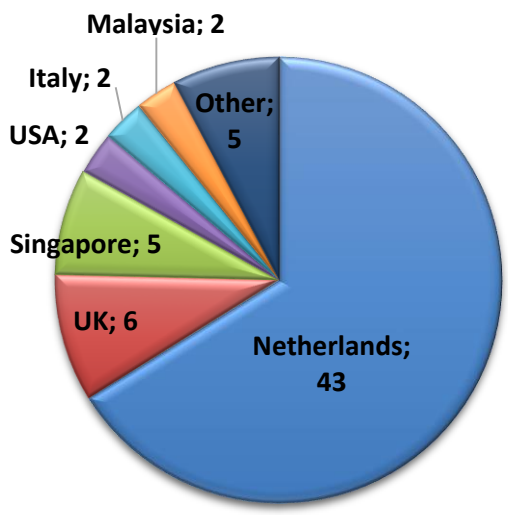

Figure 43: Potential Suppliers of Instrument Materials ECC

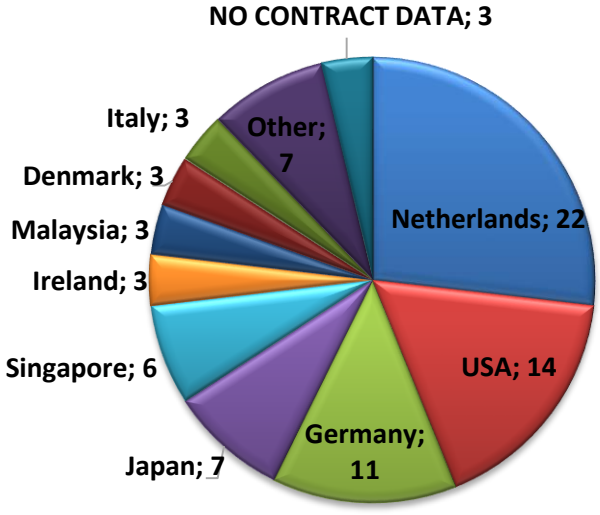

Figure 44: Actual Suppliers of Instrument Materials ECC

indicated to manufacture their goods in Japan, despite of their biddings being handled in the Netherlands. Note that the diversity of countries is higher with actual suppliers (13), when compared to potential suppliers (11).

3.5.4 PIPING MATERIALS

A total of 99 piping materials purchase orders where identified for the ECC project, compared to a total of 106 for the NKNK project, a similar amount. Of these 99 purchase orders, potential suppliers are listed for only 44 purchase orders, due to a lack of available data. The total number of potential suppliers for piping materials is 119. Their distribution among countries is shown in Figure 45. For both the ECC project (50%) and the NKNK project (42%) the Netherlands is a dominant potential supplier. This is not a huge difference, but for Germany it is. For the ECC project Germany represents only less than 10% of all potential suppliers, where its share for the NKNK project is over 25%. Italy and the UK are of similar size as a potential supplier of piping Materials. Singapore has a doubled its share compared to the NKNK project.

The distribution of actual suppliers of piping materials among countries is shown in Figure 46. Out of the 99 purchase orders, contract data on the manufacturing country was obtained for 85 purchase orders. For 14 purchase orders no data was available for the manufacturing country. Note that due to the huge difference in the number of purchase orders, which had potential suppliers (44) versus the total number of purchase orders (99), it is hard to compare potential suppliers and actual suppliers. Italy is the largest sourcing country for piping materials, representing over 25% of all actual suppliers of piping materials. Of the available data of potential suppliers it only accounted for less than 10%. The Netherlands is the 2nd largest supplier of piping materials, but this is noticeable lower than its potential. This is also due to 8 suppliers, which were originally listed as a Dutch supplier, manufacturing their goods in Italy. Apparently Italy is an attractive country to manufacture piping materials. The UK and Germany are of similar size as a sourcing country. Almost 15 % of piping materials is sourced in Asia, consisting of the sourcing countries Singapore, Malaysia and China.

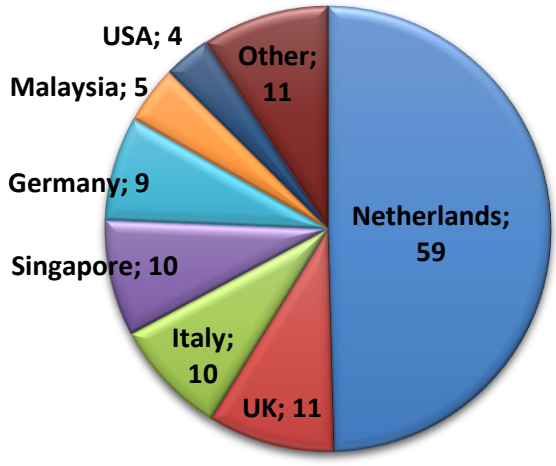

Figure 45: Potential Suppliers of Piping Materials ECC

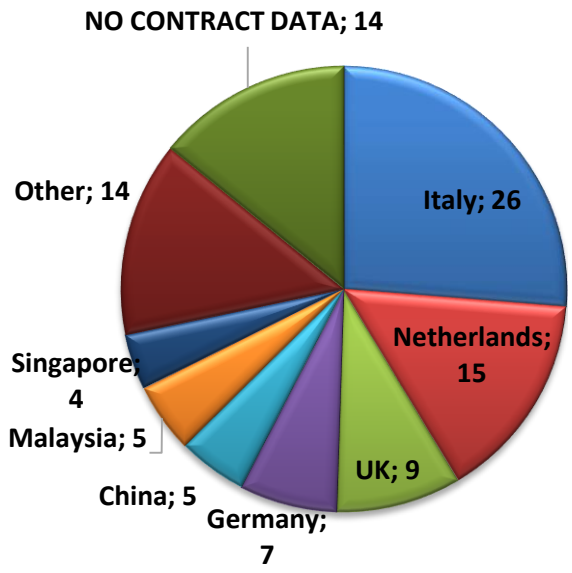

Figure 46: Actual Suppliers of Piping Materials ECC

3.5.5 SUMMARY OF FINDINGS ACUTAL SUPPLIERS OF ECC PROJECT

In this Sub-Section the findings of this Section are summarized. A quantitative summary is shown in Table 8. The most striking difference between NKNK and ECC for potential suppliers is the absence of Germany as a large country of potential suppliers for ECC. This has all to do with the nature of the NKNK project, namely its geographical location and the budgetary limitations involved. In the NKNK project the Netherlands plays a more dominant role, than for the ECC project.

The largest difference is seen for static equipment, where Korea was the most important country to source from in the ECC project. The Netherlands is not even listed as a top 4 potential of actual suppliers of static equipment. This purchase order category is dominated by Asian countries Korea, Malaysia and Singapore and 1 European country (Italy). For rotating equipment it becomes evident that the Netherlands remains a key player as a potential supplier, as well as an actual supplier. Japan

Table 8: Summary of Descriptive Statistic of Actual Suppliers of ECC Project

Category	NO of Purchase Orders (PO), Contracts (C), Bid Tabs (BT), Potential Suppliers (PS)		4 Largest Potential Supplying Countries		4 Largest Actual Supplying Countries	
Equipment Materials	PO	138	Korea	18%	Korea	14%
	BT	117	Netherlands	18%	Netherlands	14%
	C	115	Italy	13%	Singapore	8%
	PS	471	Singapore	9%	Germany	7%
Static Equipment	PO	48	Korea	30%	Korea	33%
	BT	46	Italy	17%	Singapore	15%
	C	43	Malaysia	10%	Malaysia	10%
	PS	261	Singapore	7%	Italy	8%
Rotating Equipment	PO	49	Netherlands	50%	Netherlands	26%
	BT	42	Japan	18%	Japan	10%
	C	40	USA	9%	Germany	8%
	PS	98	UK	6%	Italy	8%
Electrical Materials	PO	32	Netherlands	46%	Netherlands	31%
	BT	21	UK	14%	Germany	13%
	C	27	Japan	10%	Malaysia	13%
	PS	106	France	8%	UK	9%
Instrument Materials	PO	82	Netherlands	66%	Netherlands	27%
	BT	28	UK	9%	USA	17%
	C	79	Singapore	8%	Germany	13%
	PS	65	USA	3%	Japan	9%
Piping Materials	PO	99	Netherlands	50%	Italy	26%
	BT	44	UK	9%	Netherlands	15%
	C	85	Italy	8%	UK	9%
	PS	119	Singapore	8%	Germany	7%

distinguishes itself by being a preferred supplier for rotating equipment. The USA and UK were apparently not very attractive sourcing countries for rotating equipment. Germany and Italy were more attractive in this category.

The outstanding performance of the Netherlands as being attractive for sourcing is also seen in electrical materials, where it is both the largest potential supplier as the largest actual supplier. The UK drops a few places, but is still listed as an important actual supplier. Germany takes a 2nd place, where it surprisingly was not listed often as a potential supplier. This is mainly because countries decided to manufacture their goods in Germany instead of the country in which the office was situated, where they place their bids. Malaysia takes advantage of its geographical location and is a more important actual supplier compared to its potential.

For instrument materials the Netherlands is the largest potential supplier, but manufactures a lot of these goods in other countries. Although Dutch offices place their bids on purchase orders, the goods are quite often produced abroad. USA, Germany and Japan all have a strong Dutch connection. This is why the USA and Germany are also important players in instrument materials. Singapore is not a very attractive sourcing country for Instrument materials, indicated by the fact that it is not listed anymore among the 4 largest countries.

For piping materials Italy is surprisingly the largest sourcing country. As a potential sourcing country it occurred on the 3rd place with only a share of 8%. In the ECC project 26% of all piping materials were sourced in Italy. A contribution to this large share is due to the decision of 8 Dutch suppliers to manufacture their goods in Italy. Still the Netherlands supplies 15% of all piping materials, where the UK and Germany are also quite large. It is evident that for the sourcing of piping materials one is likely to source from these four western European Countries.

3.6 CONCLUSIONS

In this chapter it is underpinned why one should select multiple suppliers for a single purchase order. Also the limitations in selecting suppliers are discussed. An argument for selecting large numbers of suppliers is, the more bids are received, the higher the possibility of a low valued quotations. However, there are restrictions in selecting suppliers. A restriction is the approved vendor list, a list of suppliers which match the requirements for a project, with respect quality, trust, and previous experiences. Suppliers not on this list, which is compiled in consultation with the client, are not allowed to use for sourcing. Another restriction in selecting potential suppliers are financial constraints, as it is a waste effort to select supplier in a country where no budget is available. Also the administrative burden involved with communicating with large numbers of suppliers is a restriction. Sending inquiries to a large number of suppliers does not always lead to a large number of bids. In extreme cases there could be only one or, even worse, no bid for a single purchase order. This indicates that the degree of competition could be a determinant for the amount of selected suppliers, as a reasonable set of bids is desired.

Descriptive statistics are shown, for the NKNK project, per purchase order category on the amount of potential suppliers and the distribution of suppliers among countries. The Netherlands is the single largest potential sourcing country for all purchase order categories. The second largest is consistently Germany. Italy and Japan are also important players in almost all purchase order categories. The UK is a large potential supplier for instrument materials and electrical materials, where France has a notable

share as a potential supplier of electrical materials. Equipment materials has the largest number of unique potential suppliers and number of possible sourcing countries, but the lowest average number of suppliers per purchase order. Piping materials has the highest number of potential suppliers per purchase order (7.3), significantly larger than the projects average of 5.6.

It is determined whether there was a correlation between the perceived competition of procurement managers and engineers, and the number of potential suppliers that are selected per purchase order. A linear regression technique is used and propositions are tested. The most convincing proposition is proposition 4: 'A high degree of competition on the supply and the demand side is positively correlated to the number of selected suppliers'. There was a significant correlation between perceived competition and the number of suppliers that are selected. The implication of this proposition could be important in preliminary cost estimation models. It allows to estimate the average number of potential suppliers that will be selected per purchase order category, based on a questionnaire. This could be used when there is no data available yet on the potential suppliers for a project. The perceived competition is part of project context, therefore it complements on the impact of project context on the number of selected suppliers. In the next section a project similar to the NKNK project is analyzed, and the importance of project context is underpinned in more perspectives.

By analyzing descriptive statistics on the reference ECC project, which is essentially the same as the NKNK project, it was explored whether the project context is important in selection potential suppliers. The ECC project was situated in Singapore, and this was reflected by selecting a larger number of potential suppliers in that region. Korea, Malaysia and Singapore were a significantly larger potential supplier on the ECC project than they are on the NKNK project. The Netherlands has an important share in both projects, indicating the importance of the location where the engineering design of the plant is done. Germany is a large potential supplier for the NKNK project, where it had only a minor role in the ECC project, indicating the importance of budgetary constraints in a project (i.e. for the NKNK project it is easier to receive funding in Germany, than in Malaysia).

CHAPTER 4 SOURCING COST DIFFERENCES AMONG SUPPLIER COUNTRIES

This Chapter focusses on determinants of production costs of suppliers, and ultimately on the sourcing cost differences among countries. Firstly general theory on the production costs of suppliers is discussed in Section 4.1, both on the short term as on the long term. In Section 4.2, through a literature review, macroeconomic factors are listed that are possible determinants of sourcing cost differences among countries. There are five macroeconomics factor categories: Economic, Infrastructural, Labor, Supply Based, and Political. In Section 4.3 the data collection method on a recent project (ECC) is explained. The data collection focusses on different suppliers, supplier countries, and values for quotations. Also in Section 4.3 it is explained which macroeconomic indicators are selected to represent the macroeconomic factors, how these indicators are defined, and how this data is obtained. In Section 4.5 significant cost differences among sourcing countries are explored, by using a linear regression analysis and T-tests. In Section 4.6 countries are ranked according to their cost differences, from least expensive to most expensive. These sourcing cost differences among countries are substantiated with macroeconomic indicators and descriptive statistics, obtained in Chapter 3. Conclusions are drawn in Section 4.7.

4.1 THEORY ON PRODUCTION COSTS OF SUPPLIERS

In this Section general theory on the production costs of suppliers is discussed. This is done firstly on the short term, and secondly on the long term.

For short term determination of production costs a distinction must be made between fixed input and variable input. Fixed input cannot be increased in supply, within a given time period. Variable input can be increased in supply, within a given time period. Consequently, if a supplier desires to increase its output on the short run, it can only increase its variable costs. Fixed costs remain constant. Short run periods can be defined as a period of time in which at least one input is fixed. Fixed costs are subject to change on the long run, if the period of time is long enough for all inputs to be varied. A firm's cost of production depends on two elements related to the inputs used and the costs involved. The first is the productivity of the inputs. The greater their physical productivity, the smaller will be the quantity of them that is needed to produce a given level of output, and hence the lower will be the cost of that output. The second is the price of the inputs, the higher its price will be the higher the cost of production will be.

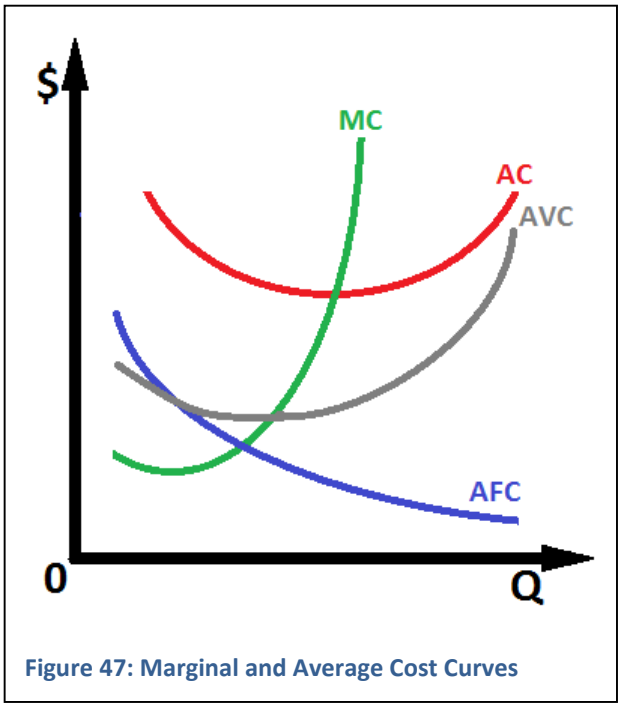

Figure 47: Marginal and Average Cost Curves

Using fixed and variable costs, there are 2 measures important for suppliers to determine their output and profitability on the short term. The first is Average Cost (AC), which is the sum of Average Fixed Cost (AFC) plus Average Variable Cost (AVC). These are measures for cost per unit of output. The second is Marginal Costs (MC), which is the costs of producing one more unit of output. Both are subject to one of the most famous laws in economics: the law of

diminishing returns. This law states that with increasing amounts used of a variable input, there will come a moment in which each extra unit of variable input will produce less extra output than the previous unit. The MC curve is following directly from this law. The shape of the AC Curve will depend on the shape of the MC curve, because as long as new units of output cost less than average, their production must pull the average cost down. This is shown schematically in Figure 47.

In the long run all inputs are considered variable. New machines can be installed, new factories can be built and new techniques of production can be used, to meet whatever output a supplier desires. These long run decisions affect the cost of production to a large extend and are often irreversible. A widely used concept is economies of scale. Economies of scale are achieved, when a firm's cost per unit of output falls with increasing production scale. There are several reasons why firms can then produce at a lower unit cost. The most important are listed below.

- Specialization and division of labor: Production is broken down into a number of simpler, more specialized tasks in which workers can reach a high efficiency degree.
- Indivisibilities: An input cannot be divided into smaller units, and large units are only economical to use above a certain output level.
- The container principle: Equipment that contains things will cost less per unit of output as size is increasing. This due to the increasing volume to surface ratio when volume is expanding.
- Greater efficiency of larger machines: More output can be produced by a given amount of input.

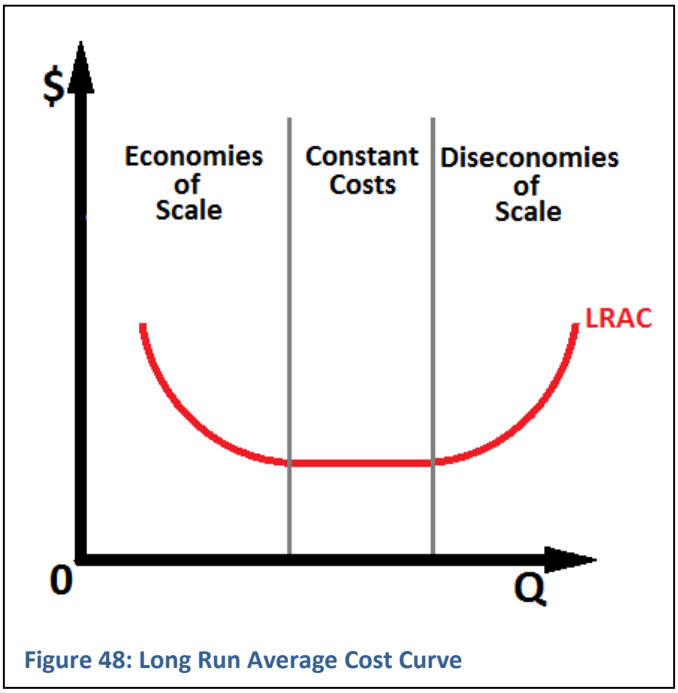

Figure 48: Long Run Average Cost Curve

However suppliers could also face diseconomies of scale, meaning the cost per unit of output increases with increasing scale of production. This could have several reasons. Managing problems arise as business structures become more complex. There could be poor motivation of workers due to boring and repetitive jobs. Complex interdependencies arising from mass production make it vulnerable to hold ups in any one part, leading to large disruptions in the production process.

When suppliers increase their scale of production, in general, they will firstly experience economies of scale. There is a limit to these decreasing costs per unit of production, due to the increasing costs arising from diseconomies of scale. Thereby a Long Run Average Cost Curve (LRAC), a curve showing the average cost of different output quantities under the assumption that all inputs are variable, will have a similar shape as a short run average cost curve. This is shown in Figure 48. This is the most typical shape, but other shapes are possible depending on the nature of the industry.

4.2 MACROECONOMIC FACTORS IN LITERATURE

Through a literature review cost significant items are revealed that could explain differences among countries in quotation values for particular purchase orders. These are predominantly macroeconomic factors, divided into 5 different categories. The first category 'economic factors' involves economic growth, tax rate, currency risk and inflation. Category 'infrastructural' involves transport time & cost, infrastructural logistics, and the IT infrastructure. The 3rd category 'Labor' describes how labor cost, turnover rate and educational level affect production costs. The fourth category is 'Supply Based'; maturity of the industry, capacity, and commodity prices are discussed. The Last category 'Political' involves the aspects of environmental regulations, and corruption. In Section 4.4, suitable indicators are selected for these macroeconomic factor categories.

4.2.1 ECONOMIC FACTORS

This Sub-Section describes the general economic factors that could affect sourcing costs of different countries: Economic growth, currency risk, inflation, and tax rate.

4.2.1.1 ECONOMIC GROWTH

Gross Domestic Product (GDP) Growth, or economic growth, is the increase in the amount of goods & services over time produced by an economy, and is measured relative to the GDP of an economy. It reflects the growth in total production, income and consumption of an economy. To compare GDPs of different countries one can use GDP per capita. GDP growth has several indirect effects on the production costs of suppliers. Firstly, GDP growth is likely to generate growth in jobs (a higher demand for labor), which results in higher labor costs. Secondly GDP growth pushes industries to the limiting factors of their capacities, resulting in diseconomies of scale. Thirdly, it increases the scarcity of raw materials; driving up their costs. Fourthly transportation costs are likely to rise due to longer transportation times, less transport available and rising energy prices.

4.2.1.2 CURRENCY RISK

Currency risk is also known as foreign exchange risk or exchange rate risk. It is a financial risk due to changes in exchange rate between two currencies. Businesses importing and exporting goods & services are exposed to the (un)anticipated fluctuations in exchange rates, with possible severe consequences. Due to globalization, currency risk is becoming increasingly important in production processes. The effects of exchange rate volatility, which can either be positive or negative, is dependent on the existence of a forward market, in which sharp fluctuations in prices can be hedged (Viaene & de Vries, 1992). To hedge against price fluctuations, premiums are charged which are additional costs in the sourcing processes. These premiums depend on the volatility. Highly volatile currencies will result in higher premiums, when compared to more stable currencies.

4.2.1.3 INFLATION

Another source of price instability is inflation. It is the general price rise of goods & services over a time period in an economy. It reflects a reduction per unit of money of purchasing power, with a positive inflation level money is losing its value. High inflationary regimes result in high price uncertainty. In these regimes it is hard to establish who the low price suppliers are, as a price observed today is not a good predictor for the future pricing levels. There is a positive relation between inflation and price

variability. This through inflation induced price variability is increased by the inefficiencies in resource allocation, due to imperfect information (Mariano, 1994). In addition, if the inflation rate is relatively lower than other countries, over time this country will become more competitive, as the goods prices will be increasing at a slower rate.

4.2.1.4 TAX RATE

The effective tax rate that a country charges on suppliers within the supply chain affects the prices at which suppliers can buy their inputs for production and sell their output. A tax rate directly increases the price of goods & services. It is shown in Figure 49, using microeconomic theory, how tax policy has a loss of social surplus as a consequence. A tax policy leads to a decrease in demand, as consumers face a higher price (P_C) than the equilibrium price (P_{eq}). Producers must reduce their output Q_{eq} to the new equilibrium output (Q_{Tax}). Taxation leads to lesser goods sold in the market at a higher price. More formally; taxation decreases consumer surplus and producer surplus resulting in a deadweight loss. Deadweight loss represents the lost social surplus, where there is no offsetting benefit accruing to some other part of society. Depending on the tax policy, taxes will affect the cost suppliers and buyers face in the entire supply chain to a certain extend. This is dependent on the absolute tax rate, the tax deductibility of business activities and how rates vary by commodity. The effective tax rate takes all of these into account. It is shown years ago by Melvin (1970) that taxes can be considered a determinant of trade.

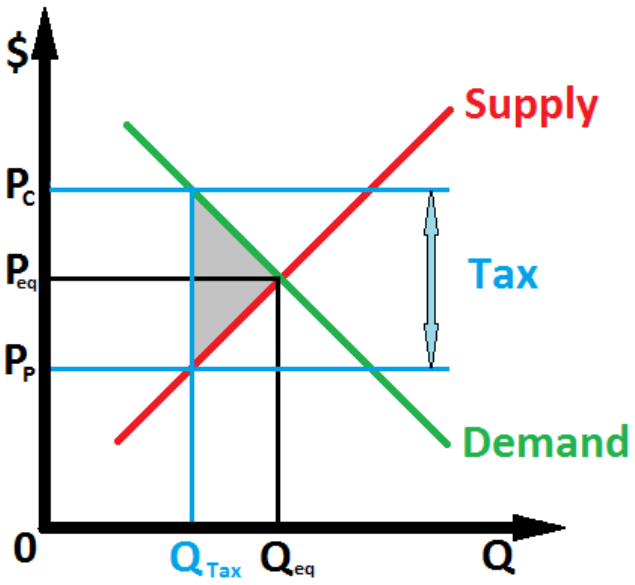

Figure 49: Deadweight loss resulting from taxation

(Grey Area indicates Deadweight Loss)

4.2.2 INFRASTRUCTURAL FACTORS

This Sub-Section deals with infrastructural aspects that can have its effects on the production costs of suppliers. This covers physical transportation factors: Transport Cost, Transport Time and Logistic Infrastructure. Also the IT Infrastructure is discussed.

4.2.2.1 TRANSPORT COST

Transportation cost is the cost associated with production and consumption due to geographical distances between supply and demand. According to a survey done by Global TCO (2010) transportation costs stand out as the most important selection criterion for the selection of suppliers. 'Hard facts', such as transport costs, are relatively easy to understand and to evaluate when making a purchasing decision. This indicates that transport costs are a substantial part of procurement costs and is crucial to take into account. There are three dimensions of costs: The financial costs of physical

transportation, the opportunity cost of time in slow processes, and the associated uncertainty with incomplete information and unpredictable arrival times (Christ & Ferrantino, 2009).

4.2.2.2 TRANSPORT TIME

Transportation time is an important determinant of transport costs. There is an increasing willingness to pay for fast delivery by buyers. Trucking firms benefit from time saving in the opportunity costs of labor and capital, and this is a straightforward reasoning for other transportation methods as well. According to Konishi, Mun, Nishiyama & Sung (2012) time savings in transportation are recognized widely to be the greatest benefits of infrastructural improvements. Christ & Ferrantino (2009) have found a linear correlation between transportation time and costs. Transportation time includes time for loading, unloading, rest breaks, customs, and waiting time.

4.2.2.3 LOGISTIC INFRASTUCTURE

The logistic infrastructure includes roads, railways, waterways, and airways. Depending on the size, weight and distance of good that need to be transported one transportation method, or a combination of these transportation methods, would be time and cost wise preferable. Cost and time associated with importing and exporting are highly associated with the effectiveness of the logistic infrastructure. Underdeveloped regions suffer from a poorly developed infrastructural network and have generally the largest time, cost, and documentation requirements, when compared to more developed regions (Christ & Ferrantino, 2009). In addition coastal areas have a significant advantage over landlocked countries, shown by the following fact: Of the top 15 exporting countries, none is landlocked (World Bank, 1998).

4.2.2.4 IT INFRASTRUCTURE

A developed IT infrastructure offers a wide range of solutions for reducing production and sourcing costs. Especially communication and transaction costs can be reduced quite easily (Boer, Harink & Heijboer, 2002). Electronic procurement (the use of IT in the purchasing process) involves electronic (public) market places, intranets, and extranets. It is not possible to assess the impact of electronic procurement by treating it as one solution, because it is not straightforward to generalize the impacts of the various forms of electronic procurement. However, it is undisputed that there are potential cost reductions by using electronic auctions, electronic catalogue systems, intelligent agent applications and electronic market places (Croom, 2000; Smeltzer and Ruzicka, 2000).

4.2.3 LABOR FACTORS

Aspects of labor that could affect production costs are discussed in this Sub-Section. These aspects are the turnover rate, labor cost, and educational level of the workers.

4.2.3.1 TURNOVER RATE

The rate at which employers gain and lose employees is called the labor turnover rate. High turnover rates are recognized as harmful to a firm's productivity, where knowledge is a core competency. Novice workers will face a learning curve, which skilled workers already have gone through, and therefore skilled workers are more productive. The turnover rate can vary widely among industries. A high turnover rate can be a result of low employee satisfaction. Unhealthy and unsafe conditions are an important predictor for industries with a higher than average turnover rate. (Guthrie, 2001)

4.2.3.2 LABOR COST

Labor differs profoundly from the sale of other goods & services. The modern world no longer permits people to be sold into slavery, or to be traded. Labor can be seen as a rent of services of employees by employers. However labor can be treated in theory as a regular good or service. There is a demand for labor and a supply. A firm hires workers up to the point where the value of the marginal product of labor equals the wage. On the supply side, a worker is willing to provide labor up to the point where the wage earned is less than the opportunity costs of that worker (e.g. time for leisure). The cost share of labor among production processes can vary widely. Knowledge intensive industries tend to have high labor costs, where routine production processes have lower production costs (Zimmerman, 1991). Technological progress can decrease the labor cost in unit production cost significantly.

4.2.3.3 EDUCATIONAL LEVEL

The educational level of employees is closely related to productivity. According to Black & Lynch (1996), a higher educational level in an establishment has positive effects on productivity on manufacturing as well as non-manufacturing firms. In their findings; an average increase in educational level of 10% increases productivity by 4.9% for manufacturing firms and 5.9% for non-manufacturing firms.

4.2.4 SUPPLY BASED FACTORS

Supply based aspects include industry specific macroeconomic factors. The possible cost effects of maturity of the industry, and the capacity is discussed. Also the prices of inputs (commodities) are noted.

4.2.4.1 MATURITY OF INDUSTRY

The maturing of an industry is characterized by improved quality, reduced production time, and reduced production costs. Organizational culture and communication, focused at a step by step improvement of production processes, must be at the basis of the maturing process. Change management, quality management, and other process control mechanisms must be in place to achieve higher efficiency of resources and to track progress. Mature industries are characterized by high working practice standards, professional qualifications of production processes, and a low Lost Time Incidence (LTI) (Sarshar, Finnemore, Haigh & Goulding, 1999).

4.2.4.2 CAPACITY

The capacity of an industry is directly related to its cost of production. Regions with a higher than average capacity are likely to achieve economies of scale, and will be able to sell its products for a lower price or a higher profit margin. In the case of an industry reaching its capacity constraints, it will experience diminishing returns and may eventually demand higher prices. This is discussed in more detail in Section 4.1.

4.2.4.3 COMMODITY PRICES

The impact of raw material costs on the production of manufacturing firms differs per industry. Some (e.g. piping materials), where raw material cost is a large share of the total costs, are vulnerable to commodity price fluctuations. Others (e.g. instrument materials) are not likely to have severe

differences in production costs when commodity prices fluctuate heavily. The effects of rising commodity prices on prices of manufactured goods are only short term. Bloch, Fraser & MacDonald (2010) have shown, although manufacturing prices may rise on the short term with price shocks in commodity prices, this is self-correcting. This is because the supply of commodity prices in the long run is perfectly elastic. The positive relationship between movements in the world's commodity prices and industrial production, as shown by Bloch & Sapsford (2004), is seen as a key link between the world's business cycle and inflation.

4.2.5 POLITICAL FACTORS

Political aspects that could affect the production costs of suppliers are environmental regulations installed by governments. Also a level of corruption could be a determinant of sourcing cost.

4.2.5.1 ENVIRONMENTAL REGULATIONS

It is a conventional wisdom that environmental regulations increase the production costs of manufacturing firms, as it requires plants to update their production process to meet the new standards. However, Porter (1991) argues that more strict environmental regulations enhance growth of productivity, as it forces firms to rationalize their operations. Greenstone, List & Syverson (2012) have conducted large scale estimations of the economic costs of environmental regulations and have shown that they are substantial. It is measured by Total Factor Productivity (TFP), which basically shows the effects on total outputs of the imposed regulations. A decrease of roughly 4.8% in TFP is seen with emitters of particulates, sulfur dioxide, and ozone, when submitted to environmental regulations. This indicates a negative effect on productivity. Porter's predictions are true for carbon monoxide nonattainment areas, where environmental regulations increase TFP slightly, especially among refineries.

4.2.5.2 CORRUPTION

Corruption can be seen as a major hurdle to achieve business objectives. Regions facing high levels of corruption experience retrogressive consequences for manufacturing industries. Negative effects of corruption have been widely acknowledged in the literature, as it reduces investment/GDP ratio and has a negative effect on economic growth (Mauro, 1995). Wei (1997) indicates that corruption also discourages Foreign Direct Investment (FDI). The overall cost of production is increased by corruption, mainly because it distorts the competitiveness of the market. Competition on price or quality is no longer dominant in acquiring market share. An analysis done by Kimuyu (2007) has shown that corruption reduces a firm's ability to grow and to penetrate into foreign markets.

4.3 DATA COLLECTION AND PREPARATION: QUOTATIONS

In this Sub-Section 4.3.1 the data collection method on quotations for the ECC project is discussed. Additionally, it is shown in Sub-Section 4.3.2 how a data set of suppliers, purchase orders, quotation values, and countries are transformed to create categorical variables, used for statistical tests.

4.3.1 SUPPLIERS, PURCHASE ORDERS, QUOTATION VALUES AND COUNTRIES

Accurate prediction of construction costs of the NKNK project is heavily dependent upon the availability of quality historical cost data and the level of professional expertise among other things. To make predictions on the costs of future projects, it will be beneficial for the accuracy to obtain data from a similar plant in the near past. Data is collected from a previous project executed by CB&I for Shell in Singapore (ECC). This plant is very similar to the plant to be constructed in the NKNK project. A comparison of the production capacities of the plant is shown in Table 9. Purchase orders of the ECC plant are evaluated. Values of quotations from suppliers, and the countries they are located in, are taken into account. These are all retrieved from the database of CB&I. For completeness more general data is also listed for different purchase orders, such as purchase order type and name. All data to be obtained is summarized in Table 10, which includes examples for 2 different purchase orders. Note that, in this example, these are fictitious supplier names and quotation values for the sake of confidentiality.

Table 9: Production Capacities NKNK & ECC

(All figures are in Tons per Annum)

	NKNK	ECC
Ethylene	1,000,000	800,000
Propylene	450,000	450,000
Benzene	320,000	230,000

When all data was collected the data needed to be prepared for statistical testing and analysis. As shown in Section 4.2, there are many multiplicative effects affection the quotation values (Economic-, Infrastructural-, Labor-, Supply Based-, and Political factors). Therefore it is hypothesized that the data on quotation values is distributed in a log-normal fashion. For this reason, the logarithm of the price is taken.

Table 10: Example of a collected data sheet of Purchase Orders including Quotation Values

Purchase order ID	Purchase order Type	Purchase Order Name	Supplier Name	Supplier Country	Quotation Value [$]
PO-1001	Rotating Equipment	Vacuum Unit	Indart	Netherlands	259,886
			Barbara	Japan	256,454
PO-1002	Static Equipment	Cold Boxes	Dorf	Germany	1,185,190
			Kabi	Japan	1,546,221

4.3.2 DATA PREPARATION

The next step is to pool the data. In this way one can take advantage of multiple different purchase orders located in multiple different countries. This is done by creating categorical variables for each purchase order and each country. Categorical variables can take a number of limited, usually fixed number of values. In this data analysis and testing each variable can take either the value '0' or '1' and

is therefore named a binary variable. A binary variable in the field of categorical variable statistics is predominantly known as a dummy variable. The transformation of Table 10 towards a matrix of categorical variables is shown in Table 11, where the quotation from Indart is referred to as Quotation 1, Barbara as Quotation 2, Dorf as Quotation 3 and Kabi as Quotation 4. If we take the quotation of Indart, it is a vacuum pump. Therefore the variable 1 is created for quotation 1 in column 'Vacuum Pump'. The supplier is located in the Netherlands, therefore the variable 1 is created in column 'Netherlands'. In the last column the natural log of the quotation value of quotation 1 is shown. All other columns are valued 0 for Quotation 1. The process is repeated for all quotations.

Table 11: Transformed Table: Categorical Variables and Natural Log (LN) of Quotation Value

Quotation Number	Vacuum Unit	Cold Boxes	Netherlands	Japan	Germany	LN quotation Value
Quotation 1	1	0	1	0	0	12,47
Quotation 2	1	0	0	1	0	12,45
Quotation 3	0	1	0	0	1	13,99
Quotation 4	0	1	0	1	0	14,25

4.4 DATA COLLECTION AND PREPARATION: MACROECONOMIC INDICATORS

Based on the theory discussed in Section 4.2, macroeconomic indicators are selected in Sub-Section 4.4.1. These indicators are possibly highly correlated for each country. To reveal the correlations, and to reduce the set of indicators to a lower dimension, a Principal Component Analysis is done in Sub-Section 4.4.2.

4.4.1 COLLECTION OF DATA

In this sub section the macroeconomic indicators used are discussed. Almost all of the macroeconomic indicators are retrieved from the World Bank[2]. There are 2 reasons for this. The first reason is straightforward, the World Bank has numerous indicators available (331) for a total of 209 countries. The second reason is, when the data is retrieved from the same source, it can be assumed similar data collection- and calculation methods are used. All macroeconomic indicators are discussed in this Section. It is underpinned why these are used, and how they are defined. An indicator is related to the competitiveness of a country. Some indicators cannot change significantly over short time periods, were others can. Thereby some indicators can be referred as average fixed costs, and others as average variable costs of a country. The theory on fixed and average costs are discussed in Section 4.1. In this Section is tried to apply this microeconomic theory to the context of a country. The indicators are ordered on their macroeconomic factor category, and it is stated which factor the indicators represent. It is tried to select the most appropriate indicators for each macroeconomic factor. It is also discussed whether this indicator is subject to change on the short- or the long-term. The Values for all these indicators are listed in APPENDIX G.

[2] The World Bank Database for Indicators: Retrieved from http://data.worldbank.org/indicator/

4.4.1.1 ECNONOMIC INDICATOR: TOTAL TAX RATE

The World Bank provides two useful indicators for tax. One is tax revenue as percentage of GDP, and the other is total tax rate as percentage of commercial profits. Tax revenue is defined as the compulsory transfers to central governments for public purposes. This includes taxes not directly linked to manufacturing businesses. The total tax rate measures the share of commercial profits, after accounting for allowable deductions and exemptions, which is mandatory for businesses to transfer to governments. This is a more appropriate measure in the context of this thesis, as it is a direct cost factor of production. Ceteris paribus, if a country increases its tax rate, the manufacturing price of suppliers will increase. Although the total tax is a relatively stable rate it is subject to change in the short term. It can be considered more as a country's variable cost factor than a fixed one.

4.4.1.2 ECONOMIC INDICATOR: GDP GROWTH

The World Bank provides for each country the annual percentage growth rate of GDP at market prices based on constant local currency. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. An increase in real gross domestic product (i.e., economic growth), ceteris paribus, will cause an increase in average interest rates in an economy. The effect of economic growth is short term, and short term only, as prices stabilize in the long term. It can therefore be considered as a country's variable cost factor.

4.4.1.3 ECONOMIC INDICATOR: GDP PER CAPITA

The World Bank provides for each country the GDP per capita, based on midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is a measure of national wealth and an indicator for the standard of living. It can be considered to be only subject to change on the long term. It can therefore be considered as a country's fixed cost.

4.4.1.4 ECONOMIC INDICATOR: INFLATION

The World Bank provides Inflation rates for each country. It is measured by the consumer price index, which reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services. The Laspeyres formula is generally used, which can be thought of as a price index taking the bundle of goods using current prices and current quantities as the numeraire. Inflation is unstable and subject to change on the short term, although most countries have a bandwidth specified in which their inflation should vary maximally. It can be seen as a variable country cost factor.

4.4.1.5 INFRSTRUCTUTAL INDICATOR: ROADS PAVED

The World Bank provides numerous indictors for infrastructure, however not all would be fair to use in a comparison among countries. E.g. the total length of a railway network does not give a good indication of the development of infrastructure in a country, as it is highly dependent on the size and geography of a country. The same argument holds for the number of carrier departments per annum. A more appropriate measure for infrastructural development is the percentage of roads paved measured in length. Those surfaced with crushed stone (macadam) and hydrocarbon binder or bituminized agents, with concrete, or with cobblestones are counted as paved. The infrastructural development of a country is a relatively intensive and long term oriented. It is not likely to change substantially on the short-term, and can therefore be considered a fixed country cost factor.

4.4.1.6 INFRASTRUCTURAL INICATORS: MOTOR VEHICLES

One indicator to measure the physical infrastructure of a country is paved roads. To complement this a measure is needed to indicate the extent to which this infrastructure is used. This is represented by the macroeconomic motor vehicles, which measures the total number of motorized vehicles in country per 1000 inhabitants. Motor vehicles include cars, buses, and freight vehicles, but do not include two-wheelers. Population refers to midyear population in the year for which data is collected. The infrastructural development of a country is a relatively slow and long term oriented process. It is not likely to change on a short term basis, and this indicator can be considered a fixed cost factor of a country.

4.4.1.7 INFRASTRUCTURAL INICATORS: INTERNET USERS

The World Bank provides some infrastructural indictors which are related to the IT infrastructure. Some are the import and export of ICT goods, relative to their total import/exports. These however are not necessarily directly related to the IT infrastructure within a country. A more appropriate measure for IT infrastructure is the amount of Internet users relative to the population. Internet users are defined as people with access to the worldwide network. Population refers to midyear population in the year for which data are available. The IT infrastructural development of a country is a relatively intensive and long term oriented, therefore considered a fixed cost of a country. The mobile web development is more subject to change on the short term.

4.4.1.8 LABOR INDICATORS: GNI PER CAPITA

An indicator must be selected to represent the wages among countries. The World Bank surprisingly does not provide direct wage statistics. An attempt to find another source that will provide an average wage rate for all countries resulted in incomplete data sets. In addition the following conclusion is drawn by The International Labor Comparisons (ILC) program: Direct comparisons of national statistics across countries can be misleading due to differing concepts and methods, and they have discontinued their attempt to do so. Sources that lists wage rates among countries, where not complete to include all countries in this thesis, and are therefore not suitable. The World Bank database did provide GNI per capita statistics for all countries. GNI is Gross National Income converted to international dollars using purchasing power parity rates. GNI is defined by the World Bank as the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad. GNI per capita is not likely to be subjected to large changes in the short term, and is therefore considered a fixed cost factor of a country.

4.4.1.9 LABOR INDICATORS: TERTIARY SCHOOL ENROLLMENT

The educational level of the workers in a country needs to be taken into account. The World Bank provides indicators for the level of education within a country, a total of 42. The indicators range from the pupil teacher ratio to the prevalence of HIV. In the context of this thesis, mainly high tech production facilities are of interest. Therefore a measure is taken to represent the educational level of the workers in high tech industries. This indicator is tertiary school enrollment, which refers to post-secondary (tertiary) educational workers. An indicator on this provided by the world bank is defined as follows: Gross enrolment ratio is the total enrollment in tertiary education (ISCED 5 and 6), regardless of age, expressed as a percentage of the total population of the five-year age group

following on from secondary school leaving. This indicator is not likely to change significantly on the short term, therefore it can be considered a fixed cost factor of a country.

4.4.1.10 SUPPLY BASED INDICATOR: COST OF LIVING INDEX

Comparing commodity prices among countries is a challenging thing to do. The World Bank does not provide data to compare commodity prices among countries. Numerous attempts are done by others to compare prices of commodities among countries. A famous one is the Big-Max index. Most indexes involve the development of commodity prices over time in countries, but is merely a measure of inflation. This does not account the real differences of input prices among countries. There is however a source, other than the World Bank, that could provide a measure for this. The Numbeo Cost of Living index[3] is an index that compares cities, as well as countries on the relative costs of commodities. These 'commodities' vary from a bus ticket, to housing prices, to a half liter of domestic draught. All are relative to a reference city which is valued 100. Countries above 100 are more expensive, and below 100 are less expensive than the reference case. To put it briefly, Numbeo uses heuristic technology on inputs by users, which periodically discards data which is most likely to be incorrect statistically. Due to higher number of inputs for a country than for a city, data showed on a country level in general contains lower noise than data showed on a city level. Although the price of a single commodity is subject to change on the short term, a whole basket of commodities is not likely to do so. This index can be considered as a fixed cost of a country.

4.4.1.11 POLITCAL INDICATORS: EASE OF DOING BUSINESS

The World Bank database does not provide direct data to take regulatory political aspects into account. However, there is a widely used indicator to account for the regulatory regime of a country, namely the ease of doing business ranking.[4] A high ranking on the ease of doing business index indicates the regulatory environment is more conducive to the starting and operation of a local firm. This index averages the country's percentile rankings on 10 topics, made up of a variety of indicators. Each topic is given equal weight. Country rankings are on an ordinal scale and therefore not suitable as indicator in principal component analysis. The selected indicator used, is a measure that shows the distance of each economy to the 'frontier'. This frontier represents the highest performance observed on each of the indicators across all countries. An economy's distance to frontier is indicated on a scale from 0 to 100, where 0 represents the lowest performance and 100 the frontier. In this way the distance to frontier measure determines the yearly ease of doing business ranking. It compares economies with one another at a point in time. Creating an attractive investment is a long term process, and this can be considered as a fixed cost of a country.

4.4.1.12 POLITCAL INDICATORS: CORRUPTION PERCEPTIONS INDEX

The World Bank does not provide a measure for corruption. Therefore a different source is used, namely Transparency International. This is a global coalition against corruption. The corruption perception index[5] was first launched in 1995, and has been widely credited with putting the issue of

[3] Numbeo Cost of Living index: Retrieved from http://www.numbeo.com/cost-of-living/

[4] Ease of Doing Business index: Retrieved from http://www.doingbusiness.org/rankings/

[5] Corruption Perceptions index: Retrieved from http://www.transparency.org/research/cpi/

corruption on the international policy agenda. Each year a country receives a score on how corrupt their public sectors are seen to be. The index is based on the daily reality for people living in these countries. The index cannot capture the individual frustration of this reality, but it does capture the informed views of analysts, businesspeople and experts in countries around the world. Fighting corruption is a long term process, and this can considered as a fixed cost of a country.

4.4.2 PRINCIPAL COMPENENT ANALYSIS

Principal Component Analysis (PCA) is used abundantly in all forms of analysis. It is appliances range from neuroscience to computer graphics. It is so popular, due to its simplicity. PCA is a non-parametric method of extracting relevant information from data sets. The number of independent variables to measure a dependent variable can be too large, be deceptive, and potentially measuring the same thing. However, the underlying dynamics of large set of variables might be quite simple, not needing such large number of predictor variables. Often it is not known what predictor variables best reflect the dynamics of the system in question. An addition there is noise, which is unexplained variance in a sample. Noise contaminates data sets, and PCA can suppress this noise. Principal component analysis is needed in the thesis, because of the large number of macroeconomic indicators involved. These indicators are thought to possibly be correlated. For example a country that is highly developed probably has a higher GDP, GNI, number of roads paved, and number of internet users. Therefore all these indicators are potentially measuring the same thing: economic development of a country.

Principal Component Analysis is a mathematical procedure for multidimensional scaling. It linearly transform variables into a lower dimensional space, while retaining a maximum amount of information that variables contain. A set of observations of possibly correlated variables is converted into a set of values of uncorrelated variables, named Principal Components. The amount principal components is always less than, or equal to, the number of original variables. The transformation to principal components results in the first principal component to always have the largest possible variance. Each succeeding component explains, in turn, the highest variance possible of the data set under the constraint that it is orthogonal to (i.e., uncorrelated with) the preceding component. Therefore principal components are guaranteed to be independent of on another.

The principal component analysis is done using SPSS Statistics, a software package used for statistical analysis (officially named "IBM SPSS Statistics"). The SPSS analyze function contains a dimension reduction section, in which a factor analysis is done. All macroeconomic indicators are selected for PCA (all values of these indicators are listed in APPENDIX G). When analyzing the output, one must firstly take the ‘Kaiser-Meyer-Olkin Measure of Sampling Adequacy’ into account. As a rule of thumb, a value of 0.6 is a suggested minimum in order to validate the use of PCA (Hair, Anderson, Tatham & Black, 1995). Its value is 0.677 so we can proceed with PCA.

Next it is important to determine the number of principal components (PC) to be extracted in order to account for the variance in the data. As the total number of macroeconomic indicators of the input is 12, the output has potentially of the same amount in PCs. Each PC has a corresponding eigenvalue. Eigenvalues measure the amount of the variation explained by each PC, and will be largest for the first PC and smaller for the subsequent PCs. An eigenvalue greater than 1 indicates that a PC accounts for more variance than accounted by one of the original variables. This is commonly used as a cutoff point for which PCs are retained, so PCs with eigenvalues lower than 1 are not taken into account. The values

to compute these eigenvalues are listed in APPENDIX G. The PC and their corresponding eigenvalues are shown in Figure 50, where PC 1 and PC 2 have eigenvalues above 1. Together they explain 73% of the variance.

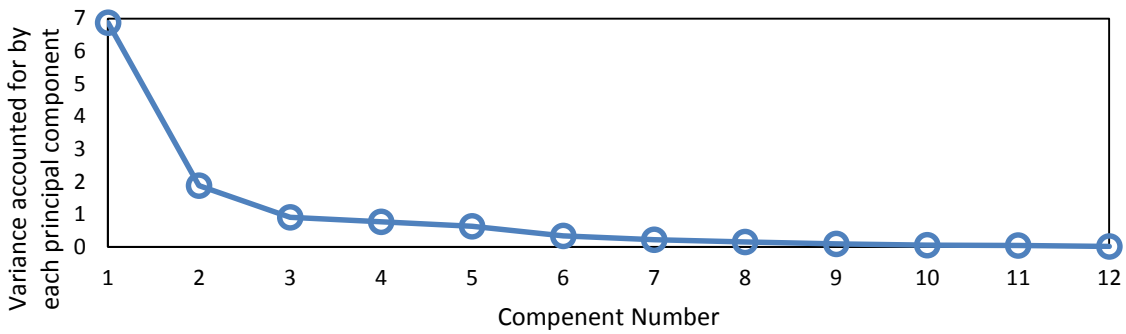

Figure 50: Principal Components and their corresponding eigenvalues

Each component has loadings on all macroeconomic indicators. These loadings are the correlations between the indicator and the component. Whether a particular loading is positive or negative is not in itself interesting, only how this relates to the other variables matters. The highest loading of Component 1 is on GDP per capita. Other indicators that have a high loading value are internet users, GNI per Capita, cost of living index, corruption index, and the ease of doing business. This shows that a country with a high GDP per capita is likely to have a large number of internet users, high GNI per capita, low corruption, and high ease of doing business. These are all indicators that show how well a country is developed. PC 1 can be seen as a component measuring the degree of development of a country. Important to note that PC1 has a high weight on the cost of living index, stating that general input prices are higher in developed countries. PC 2 has the highest loading on total tax rate. Other loadings are not as high as seen with PC 1, but GDP growth, and tertiary school enrollment is also relatively high loaded. It means that countries with a low tax rate, are likely to have a high GDP growth and a low tertiary school enrollment. The PCA shows that PC 2 can be seen as an economic variable measuring taxation, i.e. direct input costs. To a lesser extend PC 2 represents GDP growth, inflation, and educational level of the worker.

Table 12: Component Weights of Macroeconomic indicators

Macroeconomic Indictor	Component	
	1	2
Total tax rate	-,568	-,831
GDP per Capita	,963	,086
GDP growth	-,241	,723
Inflation	-,512	,561
Roads Paved	,660	,034
Motor Vehicles	,507	-,635
Internet users	,849	-,147
GNI per Capita	,866	,095
Tertiary school enrollment	,291	-,600
Cost of living index	,830	-,183
Corruption index	,901	-,083
Ease of doing business	,847	-,035

Hereby, we can define PC 1 and PC 2 more qualitatively. PC 1 represents predominantly macroeconomic indicators measuring economic development, not subject to significant changes in the short term. PC 2 represents predominantly macroeconomic indicators total tax rate and GDP growth, which are subject to significant changes in the short term.

Having these component weights on macroeconomic indicators, these weights have to be translated to a factor score per country. As there are 2 components, each country

will have 2 factors scores. SPSS has a function in PCA to calculate and store the factors scores per country. The Values for country factors scores are listed in APPENDIX G. All 12 macroeconomic indicators of all countries are now transformed into two factor scores per country. These country factor scores are used in Section 4.6, to explain significant cost differences among countries.

4.5 LINEAR REGRESSION ANALYSIS ON PRICE DIFFERENTIALS

In this Section a linear regression analysis is done, to explore the differences in quotation values among countries. The data set used for this analysis is described in Section 4.3. The linear regression is done using SPSS Statistics, a software package used for statistical analysis (officially named "IBM SPSS Statistics"). At least 1 quotation value was obtained for a total of 205 purchase orders. In total 540 quotation values are retrieved from the CB&I database, all converted to US Dollars. The suppliers which submitted the quotations are located in a total of 24 countries. Using excel, a matrix containing categorical variables was generated consisting of 231 columns (total number of purchase orders, plus the total number of countries, plus a quotation ID number, plus the natural log of the quotation value). This method is discussed in more detail in Sub-Section 4.3.2. The number of rows in this matrix is equal to the number of quotation values (540). This is summarized in Table 13.

Table 13: Categorical Matrix Characteristics for Statistical Analysis

Matrix Characteristics	Amount
Purchase Orders	205
Quotations	540
Countries	24
Values per Quotation	1
Number of Columns	231
Number of Rows	540

The excel matrix is imported into SPSS. The analyze tool for linear regression (ANOVA) is used. The natural log of the quotation value is selected as the dependent variable. All countries and all purchase orders were selected as independent variables. Because there is a linear dependence with an intercept calculated in the regression analysis, one category-level vector is excluded from the analysis. One country and one purchase order should be excluded, acting as a base case (or reference group). The base country selected is ‘the Netherlands’, and for the equipment type the purchase order ‘Stainless Steel Vessels’ is selected as a base case. SPSS considers these as ‘excluded variables’. The linear regression (ANOVA) output is shown in Table 14, for 15 countries with the largest number of values for quotations (n). The column denoted with ‘B’ indicates standardized regression coefficient. The column denoted with ‘St E’ lists the standard deviation of the regression line. The column denoted with ‘t’ represents the t-statistic. The column denoted with ‘P’ contains the country’s P-Value.

Analyzing Table 14 we can conclude which countries have quotation values that are lower than the base case the Netherlands, and which are higher. The less expensive countries have a negative value for both the regression coefficient as the t statistic. These are Austria, Denmark, France, Indonesia, Ireland, Korea, Malaysia, Romania, Sweden, Switzerland, Thailand, and UAE. The countries that are more expensive, relative to the base case the Netherlands, are Belgium, Germany, India, Italy, Japan, Portugal, Singapore, Spain, UK and USA. Stating that they are cheaper or more expensive just on the basis of a regression coefficient does not mean that they are significantly cheaper. For significance testing one can look at the P values for the linear regression output. It can be concluded that there is only one significant result (i.e. a P-Value below 0.05). Indonesia is the only country with a P-value below 0.05, meaning that using regression statistics this is the only country significantly different (cheaper) from the base case, the Netherlands. In the SPSS output it is assumed that the residuals are normally distributed. Therefore these results can also be plotted using a normal distribution, also known as a Gaussian distribution. The equation to plot the distribution, as a function of x, for each country is shown in equation (3). In this equation μ is the regression coefficient (B) and σ is the Standard deviation (St E).

Table 14: SPSS output Linear Regression Analysis Quotation Values among different Countries

Country	B	St E	t	P	n
Austria	-,172	,546	-,314	,753	4
Belgium	,119	,273	,434	,665	7
Denmark	-,122	,543	-,225	,822	2
France	-,109	,224	-,485	,628	12
Germany	,013	,160	,079	,937	27
India	,211	,335	,631	,528	4
Indonesia	-,926	,304	-3,049	,002	6
Ireland	-,780	,422	-1,848	,066	3
Italy	,087	,149	,583	,560	44
Japan	,076	,152	,504	,615	28
Korea	-,241	,144	-1,679	,094	63
Malaysia	-,121	,172	-,704	,482	32
Portugal	,283	,642	,441	,660	1
Romania	-,079	,665	-,118	,906	1
Singapore	,014	,143	,096	,923	46
Spain	,091	,216	,419	,675	13
Sweden	-,196	,512	-,382	,703	3
Switzerland	-,018	,319	-,057	,955	5
Thailand	-,199	,255	-,781	,435	8
UK	,021	,145	,148	,883	34
UAE	-,362	,484	-,749	,455	2
USA	,156	,194	,808	,420	25

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{(x-\mu)^2}{2\sigma^2}} \qquad (3)$$

The normal distributions for all countries are plotted in APPENDIX E. Due to the large number of countries plotted in one graph, and their relative small differences in mean and standard deviation, this representation of the results looks chaotic. Therefore a small selection of countries has been made, on the basis of high significance and differences in means. Such a plot does not contain more information than what is shown in Table 14, but visualizing an output can give a better view of the probability distributions among countries. This is plotted in Figure 51. All distributions are relative to the base case (the Netherlands), which is situated at the value 0 on the X-Axis. All distributions situated left of the 0 base line are cheaper, and all situated on the right of the 0 base line are more expensive.

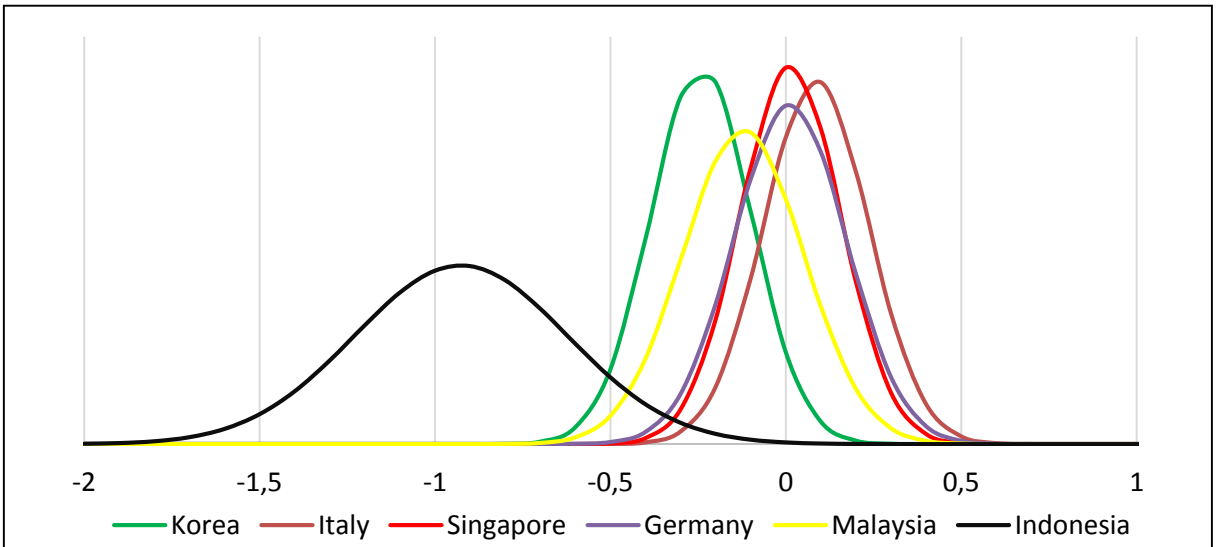

Figure 51: Plot of output Linear Regression Analysis

Clearly, Indonesia differs the most from the base case of all countries. This was also retrieved from Table 14 (because it has a high negative regression t-statistic). However it does not say whether Indonesia is significantly cheaper than other countries (e.g. Korea, indicated in green). Therefore further testing is needed, in which each country can be tested against each other country, in order to determine which countries are cost wise significantly different from one another.

The estimated linear regression coefficients are normally distributed. In the real world, to incorporate the full range of possibilities, these regression coefficients are t-distributed. The appropriate statistical test is a one-sided t-test with unequal variances, in order to determine whether countries are significantly different from one another. This test is also known as the Welch's t-Test and is shown mathematically in equation (4). In this equation $\overline{X}_C$ is the regression coefficient of a country, and s_c is the standard deviation of a country. The number of quotation values per country is denoted as n.

$$t = \frac{\overline{X}_{C1} - \overline{X}_{C2}}{\sqrt{\frac{s_{C1}^2}{n_1} + \frac{s_{C2}^2}{n_2}}} \qquad (4)$$

For each possible combination of countries (a total of 231 combinations) t-statistics are semi-automatically generated using Excel and the values from Table 14. For significance testing of these t-statistics the Welch–Satterthwaite equation is needed for each possible combination of countries. With the Welch–Satterthwaite equation an approximation is calculated of the effective degrees of freedom of a linear combination of independent sample variances. This is shown in equation (5).

$$d.f. = \frac{\left(\frac{s_{C1}^2}{n_1} + \frac{s_{C2}^2}{n_2}\right)^2}{\frac{\left(\frac{s_{C1}^2}{n_1}\right)^2}{n_1 - 1} + \frac{\left(\frac{s_{C2}^2}{n_2}\right)^2}{n_2 - 1}} \qquad (5)$$

For each possible combination of countries the degrees of freedom are generated semi-automatically using Excel. Now the t-statistic and the degrees of freedom are known for each combination of countries, and the P-Values can be calculated for significance testing. This is done by using the 'TDIST' function in excel for a one sided-t-test. All combination of countries with a P-Value below the significance testing level of 0.05 are shown in APPENDIX F, with a total 67 significant differences between countries.

In the first linear regression analysis, the Netherlands was acting as a base case, and therefore its regression coefficient and the standard deviation could not be determined. The entire process is repeated with Korea as a base case, to determine whether there are significant differences between the Netherlands and other countries. This resulted in significant differences for the Netherlands with 7 other countries. These are included in the table in APPENDIX F.

One can read the table in APPENDIX F as follows. The first tested combination of countries with a significant difference in quotation values is 'Austria vs. Indonesia'. The t-statistic is positive, meaning that Austria is significantly more expensive than Indonesia (P-Value of 0.03). Another example is 'France vs. Italy'. The t statistic is negative, meaning that France is significantly cheaper than Italy (P-Value of 0.01). Having 74 of these relations poses difficulties to present a definitive outcome, in which the countries are ranked from least expensive to most expensive. To the best of my knowledge there is no specialized suitable software available, which can generate the desired output with an input of 74 'cheaper than'/'more expensive than' inputs. An experimental analysis of this data is done using MS-Project, where the Gantt Chart tools are used for summarizing and visualizing the 74 inputs.

4.6 COST RANKING OF COUNTRIES

The Gantt Chart Tool of MS project is designed to provide a schedule for project managers. Project managers can fill in tasks that need to be completed in a project in MS project. The duration of tasks and which tasks are dependent of one another can be included. For example if we need Task A and Task B to be completed before Task C can be started, Task C will be automatically scheduled after the period in which Task A and Task B are scheduled to be completed. We can take this tool to the advantage for this data processing as follows. If Country A and Country B are significantly more expensive than Country C, we known that Country C must be 'scheduled' before Country A and Country B. With this approach the least expensive countries will be 'scheduled' first, the countries that are 'indistinguishable' of one another countries will be 'scheduled' at the same moment in time, and the most expensive countries will be 'scheduled' at the very end of the 'project schedule'.

The result is shown in Figure 52, where the Gantt Chart is exported from MS project and adjusted to fit this purpose. A detailed Gantt Chart shows a critical path, those are the scheduled tasks that do not have any slack with respect to their following up tasks. For the use in this data analysis the critical path, indicated in red in the Gantt Chart, confirms that a red country is significantly less expensive than the countries located on the right-side of that country (which can either be red or blue). Red countries that are on the same horizontal position and are situated below one another, are statistically indistinguishable of each other. Meaning that they are evenly expensive.

By combining the position of the country in the schedule and whether a country is in the critical path (indicated in red), the countries can be ranked from least expensive to most expensive. The following is concluded: Indonesia is less expensive than Korea; is less expensive than France and Malaysia; is less expensive than Germany, UK, Singapore and the Netherlands; is less expensive than Italy, Japan and USA. For the countries in blue it is less obvious as they are not in the 'critical path'. For Ireland it can be said that it could be evenly expensive as Indonesia, could be evenly expensive as Korea, but is certainly less expensive than Switzerland, India, Germany, UK, Singapore, Netherlands, Spain, Belgium and all countries located to the right of these. For Thailand, besides that it is certainly more expensive than Indonesia and is not significantly different than Switzerland, the exact same conclusion can be drawn. For Austria, it is only known that it is more expensive than Indonesia. For Switzerland, it is only known that it is more expensive than Indonesia and Ireland. For India, it only can be said that it is more expensive than Korea and Thailand. For Spain and Belgium it can only be said that these countries are more expensive than France and Malaysia. Note that in general for all blue countries, they are always more expensive than red countries located more to the left, but not necessarily less expensive than the countries located more to the right.

Name	Successors
Indonesia	15;7;10;9;16;17;3;8;12;14;6;4;11;5;18
Ireland	15;10;9;16;17;12;14;6;11;18;13
Korea	15;7;10;9;16;17;12;8;14;11;18;13
Thailand	15;10;9;16;17;12;14;11;18;13
Austria	
Switzerland	
France	15;16;17;12;14;11;18
Malaysia	15;10;16;17;12;14;11;18;13
India	
Germany	16;18
UK	16;18
Singapore	16;17;18
Netherlands	16;17;18
Spain	
Belgium	
Italy	
Japan	
USA	

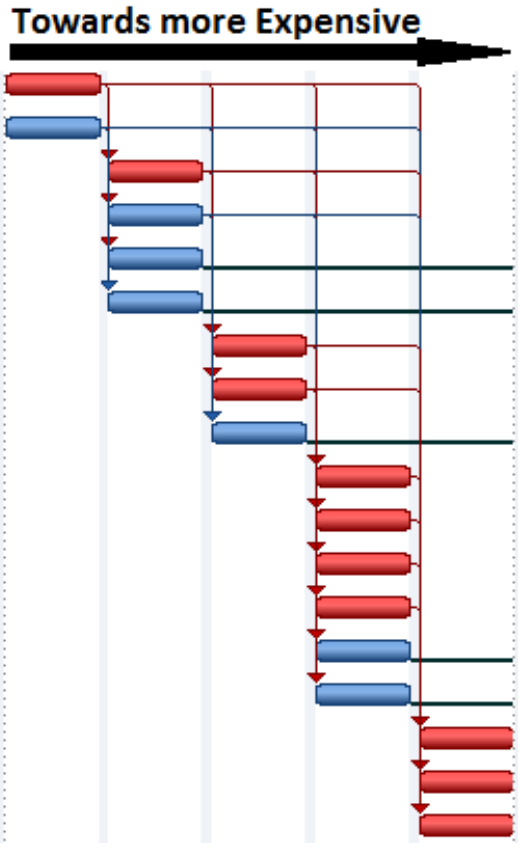

Figure 52: Gantt Chart Visualizing Sourcing Cost Differences Among Countries

4.6.1 SUBSTANTIATE RANKINGS WITH MACROECONOMIC THEORY AND STATISTICS

Data on sourcing costs differences among countries is substantiated with macroeconomic theory in this Sub-Section. This is done by using the factor scores of countries to map them all in one chart. The Factor Scores are calculated by using the SPSS function of dimension reduction in combination with the additional option to calculate and store factor scores per country, which is explained more

thoroughly in Sub-Section 4.4.2. There are 2 factor scores per country. Factor one represents the economic development of a country. It can be interpreted as long term (fixed) costs of a country, because the macroeconomic indicators of which the scores are composed of, are not likely to change on the short term. Factor 2 represents the mostly taxation, and to some extent GDP growth. These are indicators related to economic competitiveness that is more likely to change on the short term. It can be interpreted as short term (variable) costs of a country. The 2 country Factor Scores are plotted, for the countries assigned to a certain cost category, in Figure 53. All other countries are not plotted in this graph, due to graphical representation limitations and an overload of superfluous data. All countries are plotted in one graph in APPENDIX H.

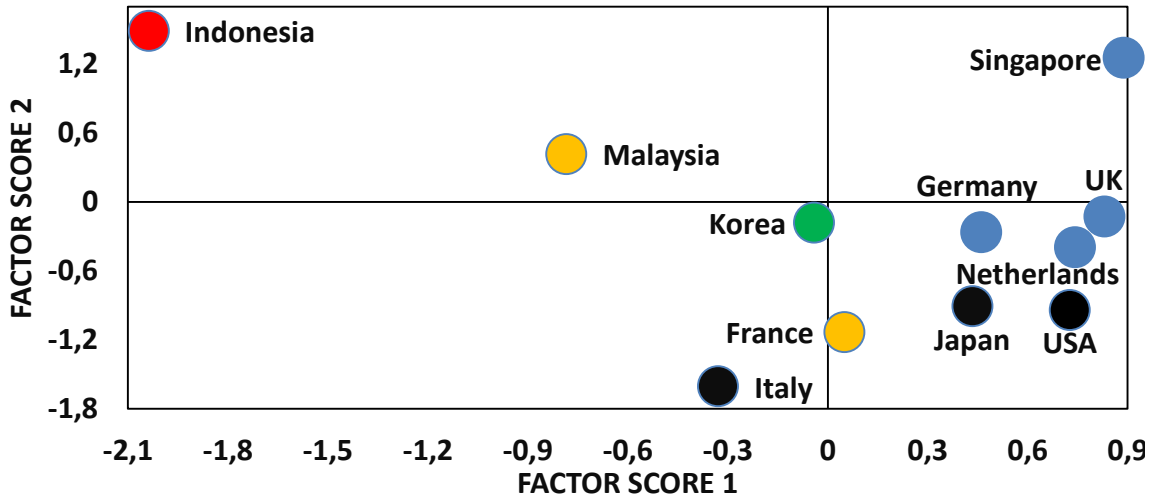

Figure 53: Factors Scores per Country and their Cost Rankings

Countries Ranked from least to most expensive: Red < Green < Orange < Blue < Black

The results are plotted in three dimensions. The first dimension is Factor Score 1, development of a country, is plotted in the X-axis. A positive value indicates more than average development which increases productivity, but also more than average general input costs. This can be concluded, as there are high component weights (Table 12) on the cost of living index (commodity prices) and GNI per capita (labor costs). The 2nd dimension is Factor 2, which is plotted on the Y-Axis. It mostly represents the taxation level and GDP growth, where a positive value indicates lower than average taxation and higher than average GDP growth. The lower taxation rate will benefit suppliers directly in decreased input costs. The 3rd dimension is indicated with a color. It represents the cost classification of a country, as shown in Figure 52.

The least expensive country Indonesia, indicated in red, is in the upper left corner in Figure 53. This means it scores the lowest on country development (Factor Score 1). In addition Indonesia has the highest score for factor 2, meaning the highest total score on taxation and to a lesser extent on GDP growth. As taxation has a negative value in PC 2, this means Indonesia has a low level of taxation. Apparently the combination of a high negative score on factor 1 and a high positive score on factor 2 leads to less expensive quotations, i.e. Indonesia is the least expensive country. Explaining why such a low developed country is able to produce so cheaply needs a more thorough analysis. Descriptive statistics need to be taken into account, to determine what type of equipment is manufactured in this country. Although Indonesia seems to be a very competitive country cost-wise, it is only so in a few

types of equipment. Examples of equipment manufactured in Indonesia are piping supports, vessels, platforms, and ladders. These are equipment types that do need high innovative capabilities, and can be produced almost anywhere. Indonesia has the benefits of low raw input costs, low laxation, and low labor costs. It makes sense that a country that is low developed, can offer low tech products at a low price. Indonesia hasn't been listed as a potential supplier for more high tech equipment.

Korea, indicated in Green in Figure 53, is the second least expensive country. It scores average (close to zero) for both factor 1 and factor 2. The average score for factor 1 can be explained by analyzing its macroeconomic indicators: although Korea scores well above average for IT infrastructure, and on the ease of doing business, it scores lower than average on GDP & GNI per capita, and on the corruption index. The average score from factor 2 arises from one of the lowest tax rates of all countries, in combination with the highest educational level of the worker (educational level of the worker has a weight of -0.6 on component 2). The country is more developed than Indonesia, but not as developed as most western countries. The reason it is competitive is not only due to the low taxation in that country. A second reason results from the descriptive statistics in Section 3.5. Korea mainly provides static equipment, and is mostly active in columns, vessels, heat exchangers, and reactors. Most of the equipment offered by Korea is more technologically advanced than what Indonesia is offering, but is certainly not as advanced comparing it to the equipment types that more developed countries are offering.

Malaysia and France seem to be far apart in in Figure 53 from when comparing factor scores, while they are both in the same cost category. Malaysia scores low on factor 1, which represents the development of that country. When analyzing its macroeconomic indicators, Malaysia scores significantly lower than average on GDP & GNI per capita, cost of living, and the corruption index, but to a lesser extend when compared to Indonesia. Analyzing the indictors of factor 2 we can conclude Malaysia has a mildly low taxation rate, and a low educational level. From the descriptive statistics Section 3.5 we can conclude that Malaysia is only big in static equipment and electrical. Malaysia is less differentiated in static equipment when compared to Korea, is a somewhat lower tech company than Korea. The electrical equipment offered by Malaysia is also not high tech: Cables.

France scores average on Factor Score 1. This is mainly because it scores slightly below average for most indicators involved in PC 1, but it scores well for infrastructure and the ease of doing business. However, France scores lower than average on Factor Score 2, mainly due to its high taxation rate. Although it can be concluded from Section 3.5 that France only has a notable share in electrical equipment, suppliers from France are active in multiple purchase order categories. France is only sporadically selected as a potential supplier, but offers attractive bids for electrical equipment and rotating equipment. The rotating equipment offered by France is more technologically advanced than static equipment, i.e. intellectual property has a larger share in the added value of equipment. It can be concluded that, although Malaysia and France are both the same cost category, they supply different kind of equipment. Malaysia has competitive advantage in supplying relatively low tech equipment for a competitive price, due to low input costs. France takes its competitive advantage in supplying more high tech equipment for a competitive price.

The 2nd most expensive country category (indicated in blue in Figure 53) consists of Netherlands, Germany, UK, and Singapore. All of these countries are, when analyzing Factor 1 scores, part of the most developed countries. All have higher than average GDP & GNI per capita, infrastructure (except

for Singapore), and cost of living. Singapore scores best of all countries on the Ease of doing business index and also has a very low perceived corruption, and is thereby the most developed country according to Factor Score 1. For Factor Score 2, the Netherlands, Germany, and the UK all have a similar value. Singapore is significantly different. This is mainly because Singapore has low taxation rate, and a low educational level of the worker, indicated by one of the lowest rates for tertiary school enrollment. Both contribute to aberrant Factor 2 scores, compared to the other countries in the same cost category. That the Netherlands, Germany, and the UK are in the same cost category and have similar values for the cost factors is reflected in the conclusions drawn in Section 3.5. All of these countries are in the top 4s shown in Table 8 of all purchase order categories except static equipment. That Singapore differs in Factor score 2, is also in accordance with Section 3.5, where it is in the top 4s of static equipment, instrument materials and piping materials. It is shown to only offer competitive prices in Static Equipment, as it is only a potential- and not a significant actual supplier in the other categories.

The most expensive country category (indicated in black in Figure 53) consists of Italy, USA, and Japan. USA and Japan have similar values for Factor Score 1 and Factor Score 2, consequently it is not surprisingly they have similar costs. Italy seems to be a bit of an outlier in both Factors, although it is in the same cost category. Japan and USA have similar values for most important indicators of PC 1. Noticeable differences are that USA has superior ease of doing business over Japan, where Japan has one of the highest costs of living of all countries. Italy differs from Japan and USA in Factor 1 score, due its poorly developed IT infrastructure, high corruption, and low ease of doing business. The most important reason for Italy having the lowest Factor Score 2 of all countries, is its high tax rate. Both Italy and USA have superior infrastructure over Japan. Japan has exceptionally low inflation. Concluding from Section 3.5, all of the countries in this cost category are active in Rotating Equipment. Italy is less developed than Japan and USA. This is reflected in its large share in low lower tech equipment, Static and Piping Materials. In addition the USA and Japan are active in more high tech industry of instrument materials.

4.7 CONCLUSIONS

This Chapter focusses on differences in sourcing costs among countries. It is explained why there can be differences in sourcing costs, and production costs of suppliers. Firstly, some general theory on the costs (and productivity) of inputs and the determination of output price by suppliers is discussed. Secondly, through a literature review, macro-economic factors are discussed which could affect production costs of suppliers. These factors are categorized in Economic, Infrastructural, Labor, Supply Based and Political factors. For each category, macroeconomic indicators are selected to represent these factors. Thirdly, data is collected on quotations from a previous project. Fourthly, this data is submitted to statistical tests. The outcome of these statistical tests is a ranking of countries on the basis of quotation values, from least expensive country towards the most expensive ones. This outcome is substantiated by using principal component analysis on the macroeconomic indicators, and descriptive statistics of Chapter 3.

4.7.1 FACTORS AFFECTION PRODUCTION COSTS OF SUPPLIERS

- **Economic Factors.**
  - Economic Growth: *An increase in economic growth is likely to increase production costs of suppliers.*
  - Currency Risk: *Businesses importing and exporting goods & services are exposed to the (un)anticipated fluctuations in exchange rates, with possible severe consequences.*
  - Inflation: *A source of increased production costs is price instability, resulting from inflation.*
  - Tax Rate: *An increasing the tax rate is directly related to increasing production costs.*
- **Infrastructural Factors.**
  - Transportation Cost: *The cost associated with production and consumption due to geographical distances between supply and demand is directly related to total production cost.*
  - Transportation Time: *There is a positive linear correlation between transportation time and costs.*
  - Logistic Infrastructure: *Cost and time associated with importing and exporting are highly associated with the effectiveness of the logistic infrastructure.*
  - IT Infrastructure: *A developed IT infrastructure offers a range of possibilities for suppliers to reduce production costs.*
- **Labor Factors.**
  - Labor Turnover Rate: *A high labor turnover rate is harmful to a firm's productivity and therefore increases production costs.*
  - Labor Cost: *Knowledge intensive industries tend to be more vulnerable to rising labor costs than routine production process industries, with respect to production costs.*
  - Educational Level: *Higher educational levels of workers are closely related to higher productivity, and therefore lower production costs*
- **Supply Based Factors.**
  - Maturity of Industry: A *mature industry is characterized by improved quality, reduced production time, and reduced production costs.*
  - Capacity: *Industries of scale are likely to have lower production costs, where industries reaching capacity constraints are likely to demand higher prices for their goods & services.*
  - Commodity Prices: *Rising commodity prices increase production costs only on the short term.*
- **Political Factors.**
  - Environmental Regulations: *These regulations increase the production costs of manufacturing firms, as it requires plants to update their production process to meet new standards.*
  - Corruption: *The overall cost of production is increased by corruption, mainly because it distorts the competitiveness of the market.*

4.7.2 EXPLORING COST DIFFERENCES AMONG COUNTRIES

Data is collected from a previous CB&I project executed for Shell in Singapore (ECC), which is a similar plant as the plant to be constructed in the NKNK project. For purchase orders of the ECC plant the values for quotations, their corresponding potential suppliers, and their country of manufacturing are listed. At least 1 quotation value was obtained for a total of 205 purchase orders. In total 540 quotation values are retrieved from the CB&I database, all converted to US Dollars. The suppliers are located in a total of 24 different countries. This data is pooled to take advantage of multiple different purchase orders located in multiple different countries, by creating categorical variables for each purchase order and each country. A linear regression (ANOVA) analysis is done on the pooled data (by using categorical variables and the Netherlands/Korea as a base case). There are many multiplicative that affect the quotation values (Economic, Infrastructural, Labor, Supply Based, and Political factors), therefore it is hypothesized that the data on quotation values is distributed in a log-normal fashion. For this reason, the logarithm of the price is taken in the linear regression analysis. A one-sided t-test with unequal variances is done, on the estimated regression coefficients and the corresponding standard deviations. It is determined whether countries are significantly different (P-Value below 0.05) from one another, using the Welch's t-Test and the Welch–Satterthwaite equation. A total of 74 significant differences among countries are retrieved from the data. An experimental analysis is done

Table 15: Countries grouped from Least Expensive to Most Expensive

Least Expensive ⟷ Most Expensive				
• Indonesia	• Korea	• France • Malaysia	• Germany • UK • Singapore • Netherlands	• Italy • Japan • USA

using MS-Project to represent this outcome, which is summarized in Table 15. Each country in a column is significantly different than any other country placed in another column. Countries shown in the same column are indistinguishable of one another. The countries that are not shown could not be placed in a single column, as the tests did not reveal sufficient statistical differences to do so.

The cost ranking of countries was substantiated with macroeconomic indicators. The indicators are a measure of the competitiveness of countries. Twelve macroeconomic indicators were reduced to 2 components, using principal component analysis. Using these components, factor scores are derived for each country. Using these factor scores, and combining the countries cost categories and the descriptive statistics of Chapter 3, it could be determined in which country one should source for each specific purchase order category. For low tech special equipment, and low tech static equipment, one is most likely to receive the least expensive bids from Indonesia. The second least expensive bids in low tech static equipment can be expected from Malaysia, where cables are also less expensive than other countries. Korea offers a broad range of static equipment and is especially competitive in heat exchangers, columns, and reactors. For rotating equipment, instrumentation, piping, and all electrical equipment other than cables one should inquire suppliers in the Netherlands, Germany and the UK in order to receive the most competitive bids. One should avoid Italy, USA, and Japan as they are unlikely to offer competitive bids for all purchase order categories.

CHAPTER 5 THE ROLE OF EXPORT CREDIT AGENCIES IN PROJECT FINANCE

In this Chapter the role of Export Credit Agencies is discussed in general, and specific for the NKNK project. In Section 5.1 the key players in trade finance, and their roles are discussed. The different mechanisms used in trade finance are discussed in Section 5.2, and models are constructed for each mechanism. In Section 5.3 it is shown how different terms & conditions of Export Credit Agencies can be compared quantitatively trough an 'interest rate coefficient'. Project specific terms & conditions for trade finance in the NKNK project are discussed in Section 5.4, of which the data is retrieved through a questionnaire. The conclusions are drawn in Section 5.5.

5.1 TRADE FINANCE

To facilitate trade of goods & services between different countries trade finance is used. Trade finance is financial support in the form of loans, insurance, guarantees, and state subsidies. The goals of trade finance are to reduce risk and fill liquidity gaps related to the cross border delivery of goods & services. Only a small portion of the world trade if facilitated by other means; cash and barter (Auboin, 2009). Barter is a system of exchange where goods & services are exchanged directly, without the involvement of cash or other means of exchange. To produce goods & services, most exports rely on financial institutions for working capital. The financial institutions also provide services to undertake payment, hedge exchange rate fluctuations, and other risks that are involved in in global trade. To indicate the importance of the services for trade transactions, Auboin (2009) has estimated that over 80 percent of international trade transactions involve some form of trade finance. As global trade was estimated to be around 15 trillion in 2009, over 10 trillion worth of trade transactions involves some form of trade finance.

Singh (2010) has distinguished 4 key players in the field of trade finance. In the field there are commercial banks, private insurers, regional & multilateral banks, and Export Credit Agencies (ECAs). The latter is the main concern in this thesis, but all will be discussed for the sake of completeness. Besides solely ECAs, other key players can play a role in trade finance for the NKNK project.

5.1.1 COMMERCIAL BANKS

A commercial bank is conventionally a type of bank that provides fundamental financial services, such as accepting deposits, giving business loans, and basic investment products. Commercial banks have a role in trade finance, by providing working capital loans for exporters, bills of exchange, letters of credit, and pre- and post-sipping financing. Commercial banks can be seen as the most important player in trade finance, by accounting for 80 percent of the activities in trade finance. However, commercial banks are risk averse and focused on short term profits. Therefore, they provide mainly short-term trade credit; loans with an initial term length of 180 days. More importantly they are often not involved in the protection of buyers and suppliers from long term risks involved in global trade. However, with increasing sophistication of capital markets, export related risk can increasingly be covered by commercial financial institutions (e.g. securitization and credit default swaps).

5.1.2 PRIVATE INSURERS

Due to market-oriented reforms, there is an expansion of operations in trade finance by private insurers. Usually short to medium term loans are covered with political risk insurance and commercial

risk insurance. The same kind of financial instruments are used by private insurers as those used by commercial banks, like securitization and credit default swaps. Commercial banks and private insurers often work closely together in trade finance. For example a private insurer can provide an 'export documentary letter of credit' that allows the exporter to obtain finance, after the bank agrees that the terms & conditions of this documentary letter are met. Private insurers differ from commercial banks in the terms & conditions, and price in which the products are offered.

5.1.3 REGIONAL & MULTILATERAL BANKS

Regional & multilateral banks are created by a group of countries, to provide financing and professional advising for the purpose of development. These banks provide a number of trade finance services, to promote trade and investment among their member states. Regional & multilateral banks are mainly focused on poor and developing countries. Examples are the World Bank, the European Bank for Reconstruction and Development (EBRD), and the Asian Development Bank.

5.1.4 EXPORT CREDIT AGENCIES

Export Credits Agencies (ECAs) have traditionally been a tool for governments to support national exporting countries. Exports are important for a country's economy, as a balance of payments deficit can result in rising debt levels. Moreover, exports create employment. ECAs stimulate exports by acting as an insurer of last resort, in cases where commercial finance is not willing to cover exports. Nowadays ECAs are heterogeneous institutions in two different ways.

1. They offer a mix of financial services to exporters.
2. They have different operating and ownership structures (i.e. governmental, quasi-governmental, and commercial).

There is no definitive model for an ECA and/or its products.

Nowadays, there are over 80 countries that have an ECA. The risks ECAs take away from investors and exporters are ultimately borne by their governments. Therefore, ECAs are not allowed to compete directly with commercial institutions. Besides commercial risks (e.g. bankruptcy), political risks are often covered by ECAs on loans. These loans are frequently medium- (up to 5 years) to long-term (5-10 years), terms are associated with large projects. ECAs are critical in these projects, because commercial banks, private insurers, and regional & multilateral banks are frequently not willing to be involved in such risky, capital intensive, and long term lending (at least not for an attractive premium). Since the economic crisis of 2008, where commercial lending markets were drying up, ECAs needed to fulfill an even more important role in trade finance. Several policy measures were taken to prevent international trade markets from completely drying up.

To prevent serious market distortions by ECAs, OECD members agreed upon an 'Arrangement on Guidelines for Officially Supported Export Credits'. However, this does not mean premiums, interest rates, and terms are uniform for these ECAs. The agreement obligates ECAs to have floating interest rates, dependent on government bond yields of the domestic country. Risk premiums are to be determined by ECAs, and are merely bonded to some guidelines. The practice is, there is room for negotiation in the financing of projects.

5.2 MODELLING OF TRADE FINANCE

In 1919, the first ECA was established in the UK. It had the intention to stimulate exports to other countries, which otherwise would not have taken place. There was little interest in ECAs in the 1920s and 1930s. After the 2nd World War, large numbers of ECAs were founded by governments. A main reason was, to support postwar reconstructions in an economically exhausted world. In that period in time, all governments had the same kind of reasoning for establishing ECAs (Malcolm, 1999). Political risks in buying countries were seen by exporters as unacceptable. Banks and insurers were unwilling to cover these risks, as they saw the risks as unacceptable to their balance sheets. Exports that would otherwise have occurred, were being lost, because of the abundance of risks. A government backed ECA could provide insurance and other risk mitigation to the exporter or the exporter's bank, to take risks away from them. Thereby ECAs enable exports taking place.

For governments the primary motivation was the stimulation of exports. Countries benefit by exports in several ways. It protects and creates employment and maintains GDP growth. Moreover, exports could have political benefits, such as more robust diplomatic relations with trading countries. Important in these stimulations was, to not compete with the commercial and private markets for trade finance. The only objective was to fill the gap in the marketplace. Due to their success, more and more countries set up an ECA in the decades following the 2nd World War. This resulted in proliferation of the role and objectives of ECAs, which are now not straightforwardly linked to the initial reasoning's for establishing ECAs. In addition, the financial sector has evolved towards a sector willing to underwrite political risks on a growing scale. This harms the capability of ECAs to break even, because as an 'insurer of last resort' it acquires the least profitable business portfolio.

In line with these developments, there is no general model that can be applied for ECAs, applicable in all countries at all times. ECAs can either be fully governmental, quasi-governmental, or privately owned companies. Some are involved only in short-, medium-, or long-term business, but any combination of these is possible. They can issue guarantees and insure, or lend, but can also do both. ECAs differ vastly in size. Most ECAs underwrite both political as commercial risk, but some limit themselves to only one of these categories. Some provide only investment insurance, others only export credit insurance, but some do both. It is evident that multiple models are needed to account for differences in ECA countries, and still they should be used with caution as these models are not applicable at all times.

Firstly, a model will be described for the basic mechanism of international trade. This model is gradually expanded to incorporate banks and letters of credit, which is the most basic model for trade finance. Secondly, three models are described, illustrating how ECAs can be involved in trade finance, using supplier credit. Thirdly, a model is described how ECAs can be involved, using buyer's credit. The models described in this Section are derived from Malcolm (1999).

5.2.1 BASICS MODELS OF INTERNATIONAL TRADE

To derive a model for the basics of international trade, an importer (buyer), and an exporter (supplier) must firstly be defined. To engage in international trade transactions, the importer and the exporter must be located in different countries. In this Section they are indicated with Country X and Country Y. The exporter supplies goods & services from its country of origin, to the country in which the buyer is located. In exchange, a cash payment is done by the importer to the exporter. This is shown in Figure

54. When both the goods & services, and the cash are exchanged, the trade transaction comes to an end.

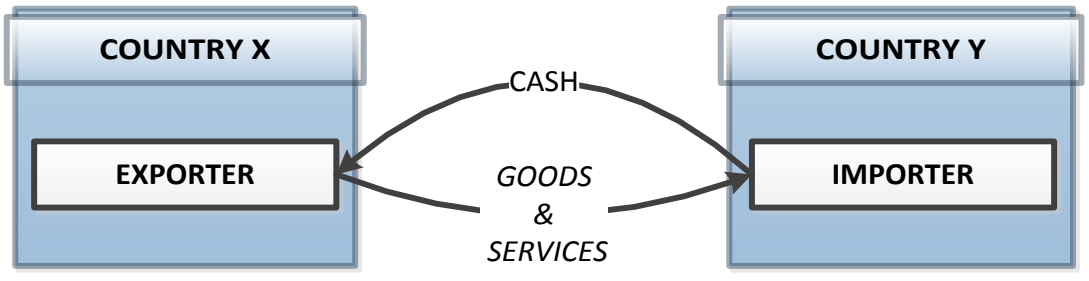

Figure 54: Basic International Trade Transaction

This simple model is unusual in the real world. It is common that payment by the importer is done, after the goods are received, normally within 180 days of receipt. A reason for an importer to delay a payment is, it does not know whether it can trust the exporters for the deliverance and the quality of the goods & services. The information asymmetry between exporters and importers poses a problem. It does not necessarily imply that both the goods & services, and the cash crosses the border. To eliminate this uncertainty banks in both countries play a crucial role. This role could be simply, providing a service to transfer money from importer to exporter (Figure 55). Hereby there still is no guarantee that the bank of the exporter will receive cash from the bank of the importer, it is merely a channel of exchange.

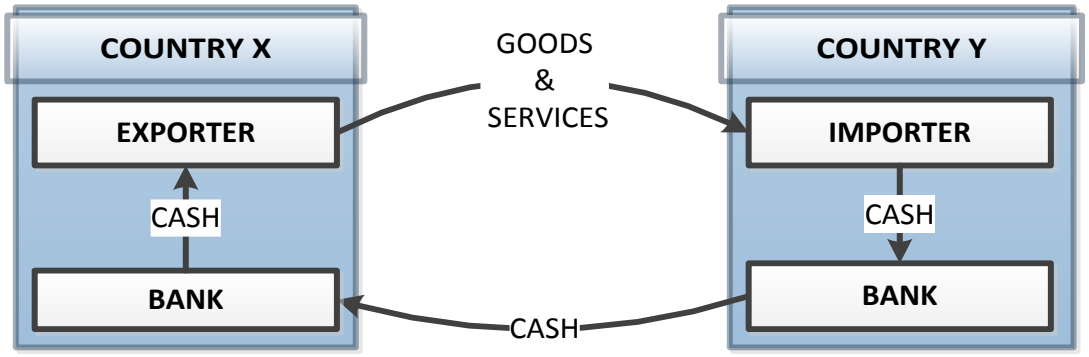

Figure 55: Basic International Trade Transaction Involving Banks

To provide more certainty to exporters they will receive a payment for their exported goods, banks can extend their role and engage in a simple form of trade finance (Figure 56). In such a transaction, the bank of the exporter sends documents giving title to the goods to the bank of the importer. The importer receives the documents only when the payment conditions are met. Thereby, an importer can only take ownership of the goods & services, when payments to its bank are done. These conditions are specified in the letter of credit. The importer is protected from uncertainty in the deliverance of goods & services with a letter of credit. A letter of credit is opened by the bank of the importer and send to the bank of the exporter. The strict conditions in a letter of credit determine the circumstances under which the bank of the exporter may release the payments to the exporter. However, the exporter's bank is not obligated to make a payment, unless it has received cash from the bank of the importer. Once the terms & conditions of the letter of credit have been fully fulfilled by the exporter, the bank of the importer is obligated to make a payment to the bank of the exporter.

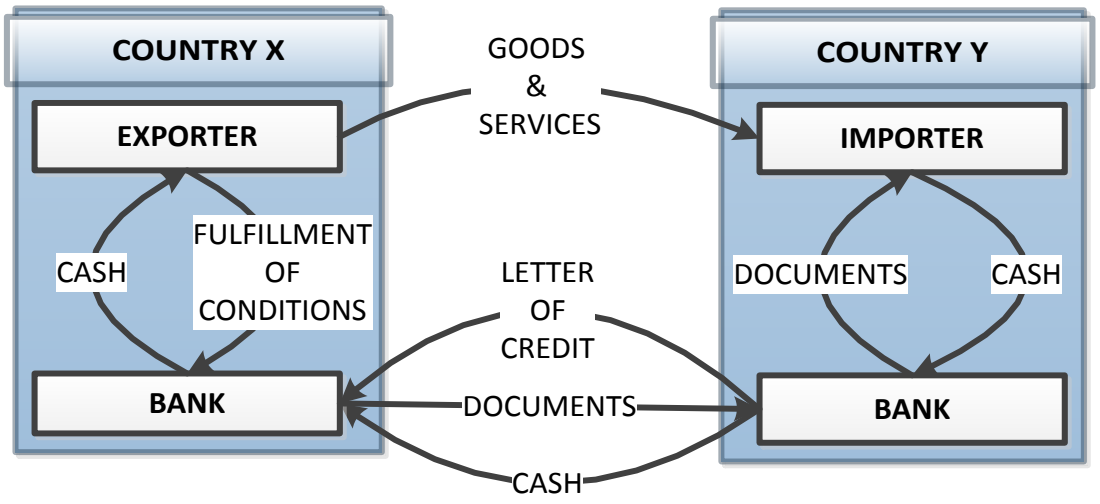

Figure 56: Basic International Trade Transaction Involving Banks and Letter of Credit

This obligation is independent on whether the importer has done the payment to its bank. If the exporter's bank is prepared to confirm the letter of credit opened by the importers bank, the gaps resulting in uncertainty can be closed. Whether or not a bank is committed to do this, depends on the confidence banks have in the ability to transfer foreign exchange. Shortages in foreign exchange reserves can lead to problematic exchange of payments.

5.2.2 TRADE FINANCE MODELS INVOLVING EXPORT CREDIT AGENCIES

Due to the risks and uncertainties importers, exporters, and their banks face in international trade transactions, Export Credit Agencies are developed. The barriers hampering international trade are reduced by transferring the risks and uncertainties to these ECAs. There are two mainstream mechanisms used by ECAs: supplier credit and buyer credit. Supplier credit is commonly used for short-term credits, which has maturity dates up to a year. For medium- to long-term credit, buyer credit is the main mechanism used.

5.2.2.1 SUPPLIERS CREDIT

The most straightforward and traditional model of ECA involved trade finance is an ECA providing supplier credit, which aims at short-term credit. This is more formally known as supplier credit insurance. The most simplistic form of this is shown in Figure 57. Goods & services are exported to the importer, according to a contractual agreement between importer and exporter. The exporter can insure itself against nonpayment of the importer, by purchasing an insurance from an ECA. The insurance can cover two different categories that could result in nonpayment, political risk and commercial risk. Commercial risk is the risk involved with insolvency or default of the importer. Political risk is the risk involved with shortages in foreign exchange reserves, war, or acts of government that reduces a firm's ability to make a payment. In this model the exporter is directly insured by an ECA.

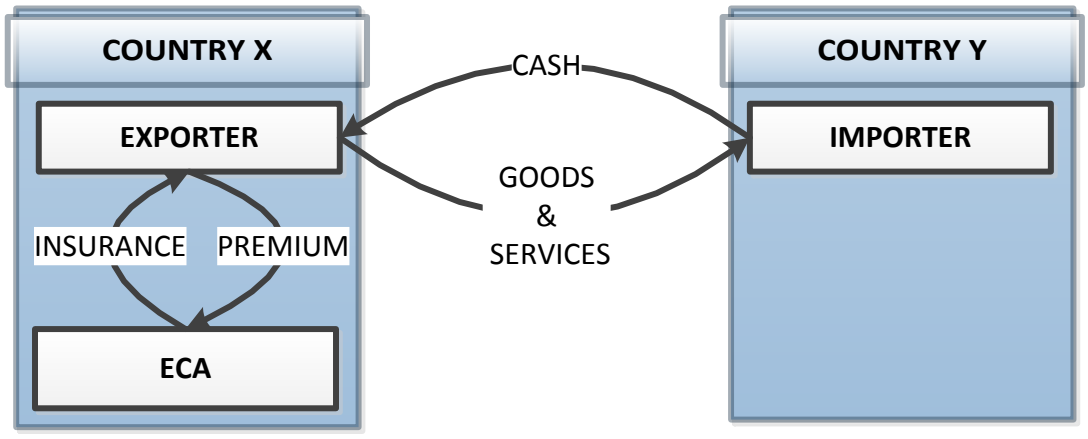

Figure 57: International trade Transaction with Supplier Credit Insurance

When the exporter does not have an abundance of cash, the exporter firstly needs cash in order to produce goods & services. The mechanism for this form of supplier credit is shown in Figure 58. The bank desires protection from the risk of the importer defaulting on payment, and the exporter's ability to make repayments. An exporter can insure the bank indirectly from defaulting on the loan (due to nonpayment of the importer) by purchasing an insurance from an ECA. This is done by paying a premium to the ECA. Banks thereby have the insurance as a security for advancing the funds to the exporter, which the exporter uses for the production of goods & services.

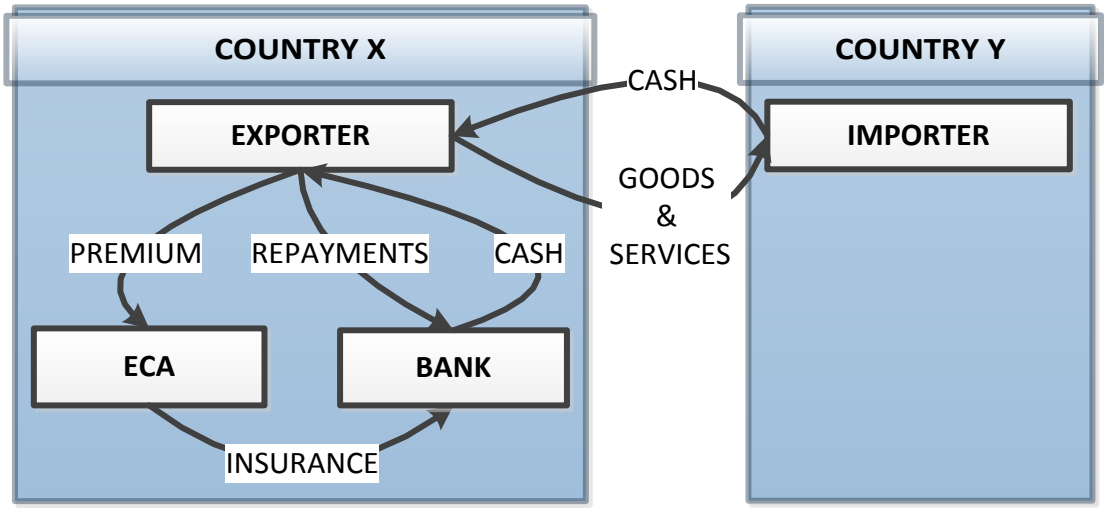

Figure 58: International Trade Transaction with Supplier Credit Insurance Assigned to Bank

Banks might prefer to directly purchase an insurance from an ECA, instead relying on the assignment of the benefits from an indirect ECA insurance through an exporter. This mechanism is shown in Figure 59. A benefit for the bank is the avoidance of risks involved with the exporter. For example, an exporter can fail to comply with the terms & conditions of the trade transaction, therefore the exporter does not receive a payment from the importer. Protection from these risks is a form of bank purchased supplier credit insurance, which involves letters of credit and documents giving title to the goods & services exchanged. Without an ECA, the exporter's bank may not agree to commit to letters of credit

issued by the bank of the exporter. The insurance policy issued directly to the exporters bank by the ECA covers the risk involved with an exporter failing to comply with the terms & conditions of the transaction.

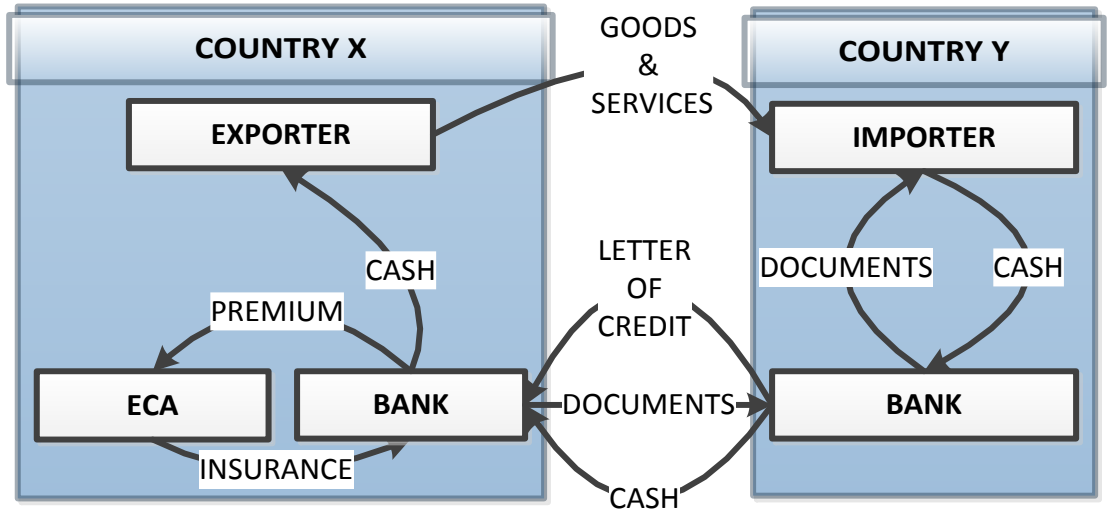

Figure 59: International Trade Transaction with Bank Purchased Supplier Credit Insurance

5.2.2.2 BUYERS CREDIT

In medium- and long term-term credit trade transactions the main mechanism used by ECAs, is named buyer credit. These terms are associated with capital intensive large construction projects (e.g. infrastructural, industrial). The mechanism for buyer credit is shown schematically in Figure 60. The basis of these trade transactions is a contractual agreement (supply contract), in which the exporter supplies goods & services to the importer. In addition to the agreement between importer and exporter, there is a parallel loan agreement between the banks of the involved countries. In this agreement the bank of the exporter provides credit to the bank of the importer. The exporter submits, when a portion of goods & services are shipped, proof that this work has been done according to contractual agreements (through certificates). Predefined amounts of the total contract value will be paid (loan drawings) by the exporters bank to the exporter, when certificates are received and approved. This process is repeated until the exporter has received the full amount, when the project is finished. The borrowing bank, the bank of the importer, repays the loan according to the loan agreement between the two banks.

ECAs are involved in buyer credit, by issuing insurance directly to the bank of the exporter. This insurance protects the bank of the exporter against possible defaults of the importer's bank, but also against bankruptcy of the exporter. The loan agreement between both banks states that the borrowing bank must repay the loan, regardless of what takes place in the supply contract. As the importing bank is responsible for the repayment of the loan to the exporting bank, the importing bank desires strict repayment terms with the importer.

The exporter itself can protect itself against risks involved. Projects that extend over a long time period are perceived as risky by exporters. Especially political risks are perceived as a serious risk for drawing on the loan. The (precompletion) risk facility provided by the ECA protects the exporter in case of a terminated supply contract, when the exporter is not to blame for this. The ECA can offer separate

supplier credit to the exporter to mitigate this risk. Therefore, ECAs can provide insurance for the exporting bank and at the same time a (precompletion) risk facility to the exporter. This 'double insurance' needs an additional agreement between the exporter and the ECA, namely a recourse agreement. It states that the ECA has to pay claims directly to the exporter's bank under the buyer credit facility. Only if the borrowers (importer's bank) default is directly linked to, or occurs at the same time as contractual default of the exporter, the ECA has the right to recover the claims to be disbursed to the lending bank from the exporter.

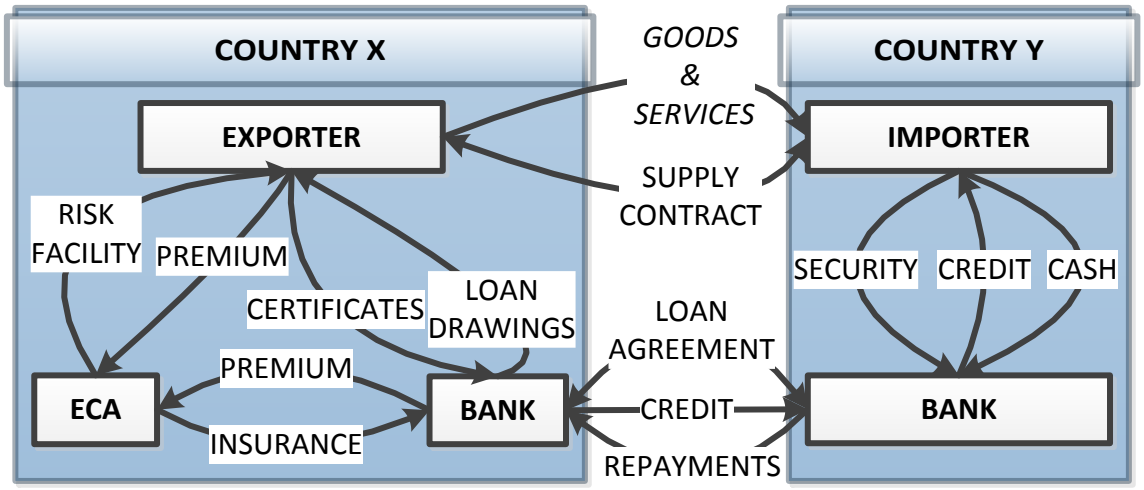

Figure 60: International Trade Transaction with ECA involved Buyer Credit

5.3 INTEREST RATE COEFFICIENT

The modelling of ECA involved trade finance is done quantitatively through an interest rate coefficient. Firstly a Net Present Value (NPV) calculation is done in order to take both the capital investment period, and the repayment term plus the number of repayment periods per loan into account. In this way we obtain comparable values for ECA involved loans including the capital investment period and repayment period of the loan, in which we can also include different repayment periods (quarterly, semiannually, annually etc.). The capital investment period and the repayment period are shown schematically in Figure 61. The abbreviations and definitions used in this Section are shown in Table 16.

Table 16: Abbreviations and Definitions for Calculations Interest Rate Coefficient.

Abbreviation	Definition
APR	$Annual\ Percentage\ Rate$
LV	$Total\ Value\ of\ Loan$
TCC	$Total\ Construction\ Cost$
TEC	$Total\ Equipment\ Cost$
TL	$Term\ of\ Loan$
i	APR/m
m	$Repayments\ per\ Year$
n	$[0, 1, 2 \ \ldots \ N]$
N	$TL \cdot m$
R_D	$Discount\ Rate$
s	$Start\ Repayment\ Period$

Loan repayments are done in equal instalments. The instalments are dependent on the number of payments per year (m) and the interest rate charged per period (i). Normally repayments are done quarterly (m=4), semiannually (m=2) or annually (m=1). The interest rate for this period is

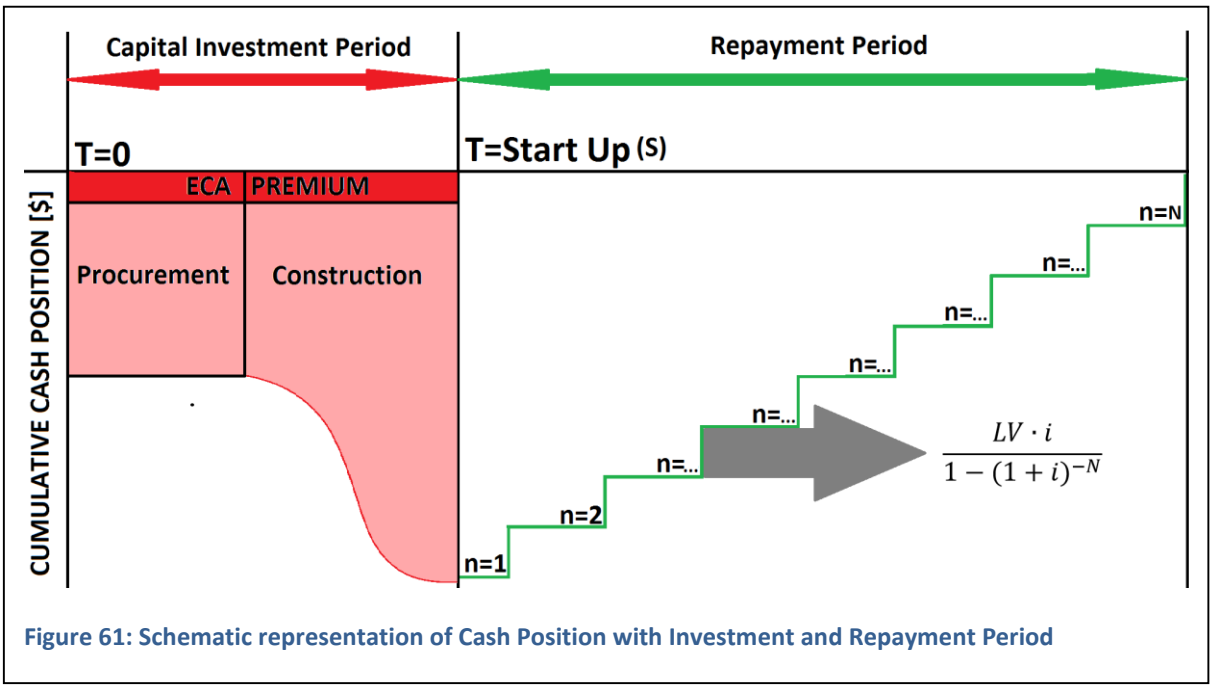

Figure 61: Schematic representation of Cash Position with Investment and Repayment Period

fixed by an annual percentage rate (APR). Dividing this rate by the number of payback periods (m) per year will give the interest rate charged per period (i). The total cash flow for the entire repayment period is the sum of each equal instalment. The total number of repayment terms is (N), calculated by multiplying the term of the loan (TL) by the number of repayments per year (m). The total cash flow of a repayment period consisting of equal instalments is shown mathematically in equation (6).

$$Cash\ Flow_{Repayment} = \sum_{n=1}^{N} \frac{LV \cdot i}{1-(1+i)^{-N}} \quad (6)$$

As these are future payments, these need to be discounted with a discount rate (D_r) to get the present value (PV) of each payment. The present value of the total repayment period is the sum of each discounted repayment. The repayment period starts at plant startup time (s), repayment is done in instalments (n) and the number of repayments per year is (m). Again, the total number of repayments terms is (N), calculated by multiplying the term of the loan (TL) by the number of repayments per year (m). This is shown mathematically in equation (7). The term $s + \frac{n}{m}$ indicates the moment in time (T) over which the instalment should be discounted.

$$PV_{Repayment} = \sum_{n=0}^{N} \frac{\left(\frac{LV \cdot i}{1-(1+i)^{-N}}\right)}{(1+D_r)^{s+\frac{n}{m}}} \quad (7)$$

This equation can be rewritten into equation (8).

$$PV_{Repayment} = \sum_{n=0}^{N} \frac{LV \cdot i \cdot (1+D_r)^{-\left(s+\frac{n}{m}\right)}}{1-(1+i)^{-N}} \quad (8)$$

We obtain the Interest Rate Coefficient (C_{IR}) by dividing the Net Present Value of the Repayment ($PV_{Repayment}$) of the loan by the total value of the loan (LV). In this way we obtain an Interest Rate Coefficient that is independent of the value of the loan and thereby comparable for different loans. Thereby ECA countries can be compared, regardless of the total value of the loan. This is shown mathematically in equation (9).

$$C_{IR} = \sum_{n=0}^{N} \frac{i \cdot (1 + D_r)^{-\left(s+\frac{n}{m}\right)}}{1 - (1+i)^{-N}} \qquad (9)$$

The Capital Investment Period Consists of ECA premiums, and the Total Installed Costs (TIC). The TIC is equal to the sum of Total Equipment Cost (TEC) and Total Construction Cost (TCC). At time T=0 all ECA premiums are paid, which are rolled over in the loan. It is assumed that simultaneously all equipment is bought. In the capital investment period the construction period has a characteristic shape, similar for different kinds of large industrial projects. This shape depends on the moments in time on which different goods & services are installed or used on site, and when cash is needed for the construction process. The total costs from sourcing to a full functioning plant, which includes transaction costs, transportation costs, local costs etc., is formally known as TIC. The construction period is broken down (for simplicity) in 1 payment part occurring at the start of year 'x'. In year 'x', the full amount is loaned for the TCC. As the starting of the repayment period is in year 's', interest is added to the loan (per year), until the start of the repayment period. This is more formally known as compound interest. As the ECA premium and the TEC are loaned at T= 0, interest is compounded from year 0 to year 's'. The TCC are loaned at T=x, therefore interest is compounded from year 'x' until year 's', and this is represented by an exponential of 's-x' over 1 plus the APR. The present value calculation of the capital investment period is shown mathematically in equation (10).

$$PV_{Investment\ Period} = ECA_{Premium} \cdot (1 + APR)^{s} + TEC \cdot (1 + APR)^{s} + TCC \cdot (1 + APR)^{s-x} \qquad (10)$$

For the calculation of the interest rate coefficient it is important that only the factors are taken into that differ per ECA country. As the TEC and the TCC is dependent on the type of project and is independent on the ECA country these should not be taken into account. It is already shown that the relative cost per ECA country is independent on the LV, and using the same reasoning this must also be true for TEC and TCC. The only factor that should be added to the interest rate coefficient (C_{IR}) is therefore the ECA premium and the compound interest rate. The definitive equation for the calculation of the Interest Rate Coefficient is shown in equation (11).

$$C_{IR} = ECA_{Premium} \cdot (1 + i)^{s} + \sum_{n=0}^{N} \frac{i \cdot (1 + D_r)^{-\left(s+\frac{n}{m}\right)}}{1 - (1+i)^{-N}} \qquad (11)$$

The interest rate coefficient method, developed in this thesis, is shown in a presentation with ING bank, NKNK (the client) and CB&I. ING bank advices CB&I and NKNK in Trade Finance for the NKNK project. They agreed on the suggested method to use it to model and compare financing costs of different ECA countries.

5.4 TRADE FINANCE IN THE NKNK PROJECT

In this Section project specific details are discussed of the NKNK project. Firstly, the key players involved in the NKNK project are described briefly. These key players are NKNK, CB&I, commercial banks and export credit agencies. Secondly, the main mechanism that is used in the trade finance for this project is explained. Lastly the terms & conditions of the trade finance are retrieved from a questionnaire and summarized.

5.4.1 KEY PLAYERS INVOLVED IN NKNK-PROJECT

Trade finance for the NKNK project involves 4 key players.

5.4.1.1 NKNK (IMPORTER)

The initiator of the project is NKNK. NKNK is the owner of the largest petrochemical complex in Eastern Europe. Compared to Russian standards NKNK is relatively highly trusted by banks and exporters. This is reflected by the risk ratings of NKNK: ECAs are likely to categorize NKNK as a CC1 (Very Good Credit Quality) or CC2 (Good to Moderately Good Credit Quality, Above Average). In the context of trade finance NKNK is the importer. NKNK does not have sufficient equity to finance the project without lending from banks, and will therefore engage in the trade finance mechanism of buyer credit.

5.4.1.2 CB&I (EXPORTER)

The main exporter in the NKNK project is CB&I. It is an exporter in 2 ways. Firstly, CB&I produces goods & services to export to NKNK. When focusing only on the total equipment costs, and not on the cost of engineering, transportation and construction, CB&I will provide at most 20% of all equipment costs. The other 80% will be supplied by secondary suppliers. As CB&I is executing the project, it is an intermediary between these secondary suppliers and NKNK. Formally CB&I is acting as the only exporter for the NKNK project, as a primary- and as a secondary supplier.

5.4.1.3 COMMERCIAL BANKS

Commercial banks are providing loans for the execution of the project. Due to the project size, no bank is willing to finance the whole project. The risk associated with such a high exposure to a project, is unacceptable for a bank. A maximum acceptable exposure for a commercial bank for projects of similar size is around 10%. Therefore a conglomerate of banks is set up, with a total of 12 banks participating. In such a conglomerate risks, as well as profits, are shared. Moreover, it ensures that there is enough equity available for loans.

5.4.1.4 EXPORT CREDIT AGENCIES

Export Credit Agencies are highly involved in the project. Without ECAs, banks will not be willing to provide loans, and suppliers will not be willing (or able) to export their goods & services. ECAs provide insurance for both exporters and lending banks. On top of that they provide recourse agreements to further protect its clients. It is shown, in the supplier country analysis in Section 3.3, that suppliers are located mainly in Europe and Asia. A total of five ECAs will be involved in the project in order to be able to cover suppliers from both continents. These ECAs are Artradius (the Netherlands), Euler Hermes (Germany), SACE (Italy), KSURE/KEXIM (Korea) and JBIC/NEXI Japan. These ECA countries are selected, because they represent a large number of the potential suppliers for the NKNK project. Each ECA listed

is also an OECD member, meaning that they support the 'Arrangement on Officially Supported Export Credits', which is often a requirement for multi ECA financed projects.

5.4.2 MODELLING TRADE FINANCE FOR NKNK-PROJECT

As the NKNK project is a long term project, the buyer credit mechanism is used for financing and insurance. The banks will require ECA coverage for the loans they are providing to the exporter and acquire this coverage through direct insurance. This direct insurance is provided by the ECA and the premium for this insurance in paid by the exporting banks. The consortium of banks demand from the exporter that a premium is paid to the ECA to acquire a precompletion risk facility, to mitigate risks involved with the importer. For example the importer could go bankrupt or cancel the project, leaving the exporter with huge debts that will not be repaid. On top of that, as the exporter is an intermediary between suppliers and the importer, this precompletion risk facility diminishes risks involved with suppliers failing to supply. Secondary suppliers failing to supply could result in losses for the exporter (CB&I), e.g. due to the delays incurred. The banks also demand a recourse agreement. In this agreement the ECA can recover losses suffered by the exporter's bank, due to project default that can be blamed on the exporter, from the exporter.

5.4.3 TERMS & CONDITIONS FOR ECA COVERAGE NKNK

To acquire the terms & conditions for ECA coverage of the NKNK project, a questionnaire is done at the trade finance consultant in this project, ING Bank. The response of ING on the questionnaire can be found in APPENDIX D. In this Section the response to the questionnaire is summarized.

5.4.3.1 BUDGETARY CONSTRAINTS OF THE ECAS

Each ECA demands that a certain percentage of the total value of the loan is true domestic content. Meaning that this percentage must be true added domestic value to goods & services. Put differently this means that a certain percentage of goods & services can be sourced from other countries, than where the ECA is situated. Atradius (the Netherlands) is the most flexible of all ECA countries with respect to this constraint. It requires only 20% of the total contract value to be true domestic content. The remaining 80% of ECA coverage can be used in sourcing from other countries. Also SACE is very flexible, when the domestic content constraint (30%) is considered. This value is however unsure as SACE does not follow the official guidelines of the OECD agreement as strictly as Artradius. One must be careful in using this domestic content constraint in a preliminary estimation of sourcing cost in different countries, as it is subject to change. Euler Hermes (Germany) is not very flexible with respect to domestic content, requiring over half (51%) of the contract value to be true added German value. ING indicates that there could even be a situation where 60-70% is required to be true domestic content. However, this is unlikely to be the case. Korea and Japan are, according to ING, not flexible at all. They require all contract value to be domestic. It is unlikely to be the case that Korea as well as Japan would allow foreign content in the contracts. These findings are summarized in Table 17.

Table 17: Minimum Domestic Content constraints of ECAs

ECA	Min. Dom. Cont.
Atradius	20%
Euler Hermes	51%
SACE	30%
KSURE / KEXIM	100%
JBIC / NEXI	100%

As the project is executed in Russia, for a Russian importer, ECAs demand that only a certain maximum percentage of the total contract value is Russian content. Without the possibility to include Russian content, the execution of the project could become problematic. An example is the transportation of equipment through Russia, which is also counted as Russian content if done by a Russifean transporter (which is often a necessity). ING is very conservative in estimating the total amount of Russian content allowed in the total contract value. The conservative estimate for each ECA is that the maximum Russian content is 15% of the total contract value. Also there is a more optimistic estimate of ING, that for each ECA the maximum Russian content could be 25,5%, except for Euler Hermes where there optimistic estimate is 19,6%. There is contradiction in the response of ING to the questionnaire. Firstly, they indicate that it is very likely for Japan and Korea to demand 100% domestic content. Secondly, they state that their conservative estimate of maximum Russian content for all ECAs is 15%, therefore allowing less than 100% domestic content for Japan and Korea.

Table 18: Maximum Russian Content constraints of ECAs

ECA	Maximum Russian Content	
	Optimistic	Conservative
Atradius	25.5%	15%
Euler Hermes	19.6%	15%
SACE	25.5%	15%
KSURE / KEXIM	25.5%	15%
JBIC / NEXI	25.5%	15%

There is no general maximum amount of ECA cover, as ECAs are the insurer of last resort. One could say there is unlimited amount of ECA coverage, as long as ECAs have confidence in the project owner and project executer. To mitigate risks associated with contracts containing (high) non domestic content, ECAs are likely to seek reinsurance with the relevant other ECAs.

5.4.3.2 TERM OF LOAN, ECA PREMIUM AND INTEREST RATES

The term of the ECA covered loans will probably be 10 years. Repayments of the loans will be done semiannually. The start of the repayment period will be at 3.5 years after the start of the procurement period. At that moment in time the first tranche of the repayment period must the paid. The loan will be fully repaid after 13.5 years.

ING cannot state with confidence in this early stage of the project what the ECA premium would be exactly. There are some tools available for the calculation of ECA premiums in a buyer credit mechanism. ING foresees minor differences in ECA premium across various ECA countries, as all will follow the OECD guidelines for officially supported export credits, with respect to ECA premiums. The differences in ECA premiums across countries are likely to have its origins in from the different risk assessments done by the ECAs, in which risk category NKNK is placed (6.2% for risk category CC1 and 7.6% for risk category CC2). The ECA premiums can be rolled over in the loans and can therefore be added to the ECA loan amount.

It is, according to ING, too early to do reasonable predictions on the interest rates. ING indicates that it can only do an estimate on the differences between the interest rates in various countries, with Euler Hermes as a base case. The resulting margin differentials are 0% for all ECAs, except for SACE. SACE is estimated to have an interest rate 1.4% higher than all other ECAs. All findings are summarized in Table 19.

Table 19: ECA Terms & Conditions, and Values

Loan Terms & conditions	Value
Term of Loan	10 years
Start of Repayment	3.5 years
ECA Premium	6.2% - 7.6%
Interest Rate Differentials	+1.4% (SACE)

5.5 CONCLUSIONS

There are four key players identified in the field of trade finance. In the field there are commercial banks, private insurers, regional & multilateral banks, and Export Credit Agencies (ECAs). Commercial banks are banks that provide fundamental financial services, and are nowadays becoming increasingly sophisticated, by covering export related short term risk. Private Insurers cover risk on short- to medium-term loans, and use the same kind of financial instruments as commercial banks. Private insurers differ from commercial banks in terms & conditions, and the price in which products are offered. Regional & multilateral banks provide financing and professional advising, mainly for poor and developing countries. Export Credit Agencies stimulate export of a country, by acting as a lender of last resort. ECAs are often quasi-governmental institutions, offering a mix of financial services to exporters, for cases where commercial finance is not willing to cover exports. To prevent serious market distortions by ECAs, OECD members agreed upon an 'Arrangement on Guidelines for Officially Supported Export Credits'. In this thesis focusing on large industrial projects, only commercial banks and ECAs of multiple countries are involved.

In addition to these key players, one must have an exporter and an importer to engage in trade finance. The most basic model in trade is an exporter exchanging goods and servicing with an importer in return for cash. This basic model is extended to a model in which banks provide services to transfer money. Also a model is shown in which banks engage in trade finance. This is done through strict conditions in a letter of credit, which determines the circumstances under which the bank of the exporter may release the payments to the exporter. The importer receives documents giving title to the goods & services, when payments conditions are met.

Trade finance models in which Export Credit Agencies are involved, are shown for supplier credit (short-term) as well as buyer credit (medium- to long-term). In the simplest supplier credit model involving ECAs, the exporter insures itself against a possible default of the importer. Political and commercial risk can be covered by an ECA. If an exporter needs cash to produce and export goods & services, an ECA (through a premium paid by the exporter) can cover for loan repayments to the bank through indirect bank insurance. Banks can insure themselves directly for supplier credit, via an ECA, and are thereby protected from an exporter that fails to comply with the terms & conditions of the trade transaction. For long- and medium-term trade transactions the main mechanism used by ECAs is buyer credit. It is modelled on the basis of a supply contract between importer and exporter. There is an additional parallel loan agreement, where the bank of the exporter provides credit to the bank of the importer. Loan drawings will be done when certificates of the exporter are received an approved, until the exporter has received the full amount for the project. ECAs are involved by issuing insurance,

for defaults, directly to the exporter's bank. ECAs are also involved in buyer credit by offering a precompletion risk facility. A recourse agreement is included, meaning defaults caused by the exporter can be reclaimed from the exporter and disbursed to the lending bank.

For large industrial projects the financing costs can be divided in a capital investment period and a repayment period. The capital investment period is modeled into 2 phases. The first phase is the procurement phase, in which all equipment is bought and transported to the site. An ECA premium is purchased in this phase by the exporter. The second phase in the capital investment period is the construction phase, in which the costs for construction are spent. The cost of the repayment period is modeled as one phase, the phase in which the total costs of the investment period are paid back to the banks. The cost for the repayment period is dependent on the term of the loan, the annual percentage rate, the number of repayments per year, the moment in time in which the repayment period starts, and the discount rate. It is shown that differences in financing cost among ECA countries can be modeled trough an 'interest rate coefficient', which is independent on the total value of the loan. The ECA premium can simply be rolled over in the loan and be added to the interest rate coefficient to take it into account, as it is assumed to be paid at the start of the procurement phase.

In addition to the financial costs of ECA countries, there are budgetary constraints. These include the maximum budget that is available per ECA country, a minimum domestic expenditure, a maximum Russian expenditure and a maximum rest of world expenditure.

CHAPTER 6 PREDICTIVE MODEL FOR SOURCING COSTS

In this Chapter a prediction will be made on the sourcing costs for the NKNK project. This will include predictions on where the purchase orders will be sourced, at what costs, and to what ECA country budgets they are assigned to. In Section 6.1 all possible data that is available for the NKNK project is collected, with respect to purchase orders, quotation values, suppliers, countries, and trade finance. When purchase orders have no listed suppliers, the number of suppliers that will probably be selected and their countries of manufacturing are estimated. This estimation is done according to analysis shown in Chapter 3, which describes the amount of selected potential suppliers per purchase order and their distribution among countries. In Section 6.2 all missing data for the values of purchase orders is estimated, by applying the order of magnitude method and the cost-time index on the reference project (ECC) data available. In Section 6.3 random values will be generated to create dummy values for quotations, based on the estimations on number of suppliers, supplier countries, methods for cost estimation, and differences in sourcing costs among countries. The input data of trade finance used in the predictive model is summarized in Section 6.4. In Section 6.5 it is shown how purchase orders, quotations, cost estimates, dummy quotations, suppliers, countries, ECA country budget constraints, and financial costs will all be combined into a single sourcing file, which can be used in a mathematical optimization model, to simulate a probability distribution of possible outcomes (Monte Carlo Simulations). The conclusions are drawn in Section 6.6.

6.1 DATA AVAILABLE FOR THE NKNK PROJECT

In this Section it is firstly described how the total number purchase orders are determined. Secondly, the number of known suppliers and their suppliers are summarized. In addition to this, it is shown how missing number of suppliers per purchase order and supplier countries are generated to fill in the missing data. Thirdly, it is shown where the data for quotation values is retrieved from and in which numbers. The main sources are the procurement and estimating department of CB&I. The number of missing values for purchase orders is also listed.

6.1.1 PURCHASE ORDERS

The basis of the cost estimating simulations are the purchase orders. Data received from procurement managers is firstly used as an input to create a sourcing excel file. The data is represented by a purchase order number, a purchase order category and a description of the purchase order. It was indicated by the procurement managers that this data was not complete, i.e. there are missing purchase orders. Procurement listed a total of 93 purchase orders. 15 for Electrical Materials, 18 for Instrument Materials, 17 for Piping Materials, 13 for Rotating Equipment, 20 for Static Equipment and 10 for Special Equipment.

The missing purchase orders are identified on the basis of the reference ECC project and in consultation with procurement. A total of 58 purchase orders are identified to be missing from the data received from procurement. There were 2 missing purchase oders for Instrument Materials, 28 for Piping Materials, 9 for Rotating Equipment and 9 for Static Equipment.

For the simulations of the NKNK project a total of 151 purchase orders are identified.

6.1.2 SUPPLIERS AND COUNTRIES

The next step is to list all potential suppliers per purchase order. For 101 purchase orders potential suppliers are listed by combining data received by procurement and an 'approved vendor list' for the NKNK project. In this list approved suppliers are listed per purchase order type, but often on a too high level to select potential suppliers for each purchase order. For 42 purchase orders the potential suppliers are based on the potential suppliers listed for the reference ECC project. There are 7 purchase orders where no data on suppliers is available: 2 purchase orders with unknown supplier data for instrument materials, 3 for special equipment and 2 for piping materials. According to the analysis done in Section 3.3 on average 4 suppliers are listed for equipment materials (and for Special Equipment), 5 suppliers are listed for instrument materials, and 6 suppliers are listed for piping materials. The number of suppliers (according to the averages) are added to the sourcing sheet and are named 'unknown supplier'. Note that these unknown suppliers still need to be allocated to a country.

The sourcing excel sheet now contains 929 potential suppliers. Of these potential suppliers there are 119 potential (non-unique) suppliers with an unknown country. Note that although some suppliers appear multiple times with an unknown country, there manufacturing location is not necessarily the same for each purchase order and therefore they are counted double as a 'supplier with an unknown country'. For electrical equipment there are 7 suppliers with an unknown country, 34 for instrument materials, 45 for piping materials, 16 for rotating equipment and 17 for special equipment. As the distribution of the potential suppliers among countries can be retrieved from the descriptive statistics in Chapter 3 per purchase order category, countries can be randomly assigned to a supplier according to this statistics.

The sourcing sheet now contains a representative number of suppliers listed for each purchase order. Each supplier which had an unknown country now has a randomly assigned country. The excel sheet is programmed in a way that each time a change is made in the sheet, or the excel sheet is opened, a new set of random countries is generated according to the distribution of potential suppliers per purchase order type. This random generation of countries is only done for the suppliers with missing supplier countries.

6.1.3 QUOTATION VALUES

The quotation values will be included in the excel sourcing sheet in 4 different ways.

1. Procurement delivers evaluated bid prices. These are quotations submitted by suppliers, which are approved by procurement. Procurement provided 12 purchase orders with evaluated bid prices. That means these have the desired accuracy to list as a quotation value in the sourcing sheet.
2. There are budget quotes. These are quotations submitted by suppliers which do not have the desired accuracy (e.g. missing parts). Nevertheless they are suitable as an input for the sourcing sheet, but are subject to change. Procurement provided 24 purchase orders with unevaluated bid prices.
3. The 3rd source is the department of estimating, which provides rough estimates on several purchase orders. In addition to the estimating department, procurement has also delivered some rough estimates. All rough estimates will be used in the sourcing sheet, but random

values will be generated (within a certain range) for each supplier (depending on the country it is located in). A total of 58 purchase orders where provided with rough estimates.

4. All other purchase orders do not have (un)evaluated quotations or rough estimates available. However, for total of 41 purchase orders the values are known in the reference project ECC. In Section 6.2 it is explained how to estimate the costs of purchase orders on the basis of that reference plant.

For a total of 16 purchase orders we do not have any value at all, these purchase order values are assumed to be 'hidden' in other purchase orders, as some are probably grouped together. Moreover the procurement control manager indicated that the values for these purchase orders are insignificant, when compared to the total sourcing costs.

6.2 METHODS FOR COST ESTIMATION

Cost estimation in large industrial projects is often called more an art than a science. Cost estimation in projects can be done in various stages of a project, from rough estimates in the inception stage to more detailed estimates in the construction phase. Therefore estimates vary from a single page calculation, to several large manuals for a more detailed estimation. The cost estimation in different stages, and the information that is needed to do more accurate cost estimation, is shown in APPENDIX I. This Section discusses two preliminary cost estimation methods: the order of magnitude method and equipment factored estimates. The equipment factored estimate is a sequel of the order of magnitude method, but it is beyond the scope of this thesis as it does not reflect sourcing costs. It is discussed in this Section to show how, on the basis of total sourcing costs, the total installed costs can be calculated (the total costs towards a full functioning plant). In Sub-Section 6.2.3 the order of magnitude method is applied on purchase orders of the NKNK project, for which no values are available yet.

6.2.1 ORDER OF MAGNITUDE METHOD

Preliminary estimates rely mostly on cost data of previous and similar projects. The data needs to be reliable and therefore the source, date, potential error, and the range of the data must be known. Most of the cost data on industrial projects publicly available is outdated, where the latest data is published in the early 1990s (Couper, Hertz & Smith, 2008). Up to date cost data is mostly obtained through solicitation of bids from suppliers. The process of deriving the cost of a new plant from the cost of a similar plant is known as a capacity-factored estimated. It relies on a nonlinear relationship between capacity and costs of plants with similar production routes, as shown in equation (12).

$$\frac{Cost_B}{Cost_A} = \left(\frac{Capacity_B}{Capacity_A}\right)^e \quad (12)$$

In equation (12), subscripts 'A' and 'B' indicate a similar plant or piece of equipment of a plant. The 'e' is the exponent or proration factor. The value of this factor is dependent on the type of plant and typically has a value between 0.5 and 0.85. If there is not sufficient information available about the type of plant a value of 0.6 must be taken for the exponent, therefore this is usually defined as the 'six-tenths factor' method. Common products of chemical plants and their corresponding proration factors are shown in Table 20. As the value of proration factor is usually a value lower than 1, plants with a higher capacity will have a lower cost per unit of production (i.e. a capacity 100% higher than the

Table 20: Products & Proration Factors

(Source: Guthrie, 1970)

Product	Factor
Butadiene	0.68
Chlorine	0.45
Ethanol	0.73
Methanol	0.60
Polymerization	0.58
Polypropylene	0.70
Sulfuric Acid	0.65
Styrene	0.60
Thermal Cracking	0.70
Vinyl Chloride	0.80

reference plant, assuming an exponent of 0.6, will lead to a cost increase of only 50%). The lower cost to capacity ratio, due to proration factors smaller than 1, have its origins in achieved economies of scale (as discussed in Section 4.1). Therefore this method is also referred to as the 'scale of operations' method. In using this method the limits of the existing technology that is used must be known. This for the fact that one might experience diseconomies of scale when scaling up a plant. When limiting factors of scaling become apparent, the proration factor will approach 1. This results in the case that constructing 2 equally sized plants will be evenly efficient (cost-wise) as construction of 1 plant with the total capacity of the 2 plants combined. However, the accuracy of this method is low, -30% to +50% of variation in actual costs versus estimated costs, and is therefore mainly used as an 'order of magnitude' estimation (Couper et al, 2008). The main benefit of this method is its low preparation effort, its simplicity, and its ability to make estimations when almost nothing is known about the project. One bust be well aware of its limitations.

The potential accuracy of the order of magnitude method can be improved by the use of cost indices. Cost indices are used to accommodate the inflationary impact of time. Specific cost indices are available for the chemical process industries. The magazine *Chemical Engineering* publishes useful cost indices in its magazines (APPENDIX J). Equation (13) describes the inflationary cost escalation of labor, material, construction cost, energy prices, and product prices in a general formula which can be applied in various industries.

$$\frac{Cost_{at\ time\ 2}}{Cost_{at\ time\ 1}} = \left(\frac{Index_{at\ time\ 2}}{Index_{at\ time\ 1}}\right) \qquad (13)$$

By using the *CE Plant Cost Index* and the *Marshall & Swift Equipment Cost Index* this equation can be used for various components of the chemical industry or for entire plants. Any further adjustments can be done to account for obvious additional costs, which were not included in the reference plant (e.g. new environmental requirements).

6.2.2 EQUIPMENT FACTORED ESTIMATES

When there is considerably more data available that just the capacity of the plant under consideration, one can do a study estimate. These estimates are typically done when 1-15% of engineering design is complete. This method often starts with the collection of delivered equipment costs Inside Battery Limits (ISBL), separately from Outside Battery Limits (OSBL). The ISBL-OSBL distinction refers to the physical boundary that separates process units from the supporting equipment. Lang (1947, 1948) introduced the estimating concept of the Total Plant Cost (TPC) by multiplying the Total Equipment Costs (TEC) by a single factor as shown in equation (14), where TEC includes the costs of deliverance of equipment.

$$TPC = TEC \cdot Lang\ Factor \qquad (14)$$

Lang distinguished, based on the type of process plant, three factors that vary only by the type of process, which are shown in Table 21. These factors include costs of piping, insulation, automatic controls, electrical work, painting etc. (Couper, 2008) of both ISBL and OSBL. There is no clear cut between the different classifications of plant and selecting a classification and its corresponding Lang Factor requires considerable judgment. Due to this limitation, there are many other different methods proposed to factor equipment to estimate TPC (Hand, 1965).

Table 21: Lang Factors

Source: Cran (1981)

Type of Plant	Lang Factor
Solid Processing	3.10
Solid-Fluid Processing	3.63
Fluid Processing	4.74

Lang's work was elaborated upon by Hand (1965) by a proposal to divide the equipment into different categories (e.g. fractionating columns, heat exchangers). A 'Hand Factor' is applied to each category of equipment to obtain its TIC and uses basically the same calculation method as shown in equation (14). When a factor is applied to each piece of equipment, one will obtain the Direct Field Costs (DFC) for ISBL; this method excludes OSBL costs which must be estimated separately. Important to note for both the Hand as the Lang factor, if a piece equipment is not made from carbon steel (e.g. stainless steel) the factors will have to be modified.

6.2.3 APPLYING THE ORDER OF MAGNITUDE METHOD FOR THE NKNK PROJECT

The order of magnitude method will be applied for the NKNK project on the basis of the ECC project. In Table 9 the capacities of the two plants are compared. This poses a small problem, because there are multiple capacities instead of only one. Capacities are listed for ethylene, propylene and benzene. For simplicity, all capacities are summed up to represent a total capacity. This summation is assumed to be one capacity for NKNK (1,770,000 tons per annum) and one for ECC (1,480,000 tons per annum), for the application of equation (12). The capacity factor used in equation (12) is retrieved from Table 20 for propylene (0.7). The capacity factored estimate, to which each purchase order of ECC should be multiplied to get an estimate of its value on NKNK, can now be calculated. The capacity factor is 1.20.

The next step is to accommodate the inflationary impact of time by using equation (13). Cost indices need to be retrieved. Cost indices are retrieved from the Chemical Engineering Plant Cost Index (CEPCI), shown in APPENDIX J. Most purchase orders for the ECC project were sourced in 2006, and the annual index for this year is 499.6. As it is unwise to extrapolate indices into the future, the most recent value available is used. The CEPCI value of 2012 is used for the NKNK project (548.6). The cost index factor, to which each purchase order of ECC should be multiplied to get an estimate of its value on NKNK, can now be calculated. The cost index factor is 1.10.

The 41 missing values for the purchase orders of NKNK described in Sub-Section 6.1.3, can now be estimated on the basis of similar purchase orders of the ECC project. This is done by multiplying the value of the missing purchase order by the capacity factor and the index factor. The next step is to create dummy quotations for the listed suppliers, based on the estimates for missing purchase orders. Where possible, these dummy quotations will take significant differences of sourcing costs among countries into account. This is shown in the next section.

6.3 DUMMY QUOTATIONS

There are no (un)evaluated quotation values available for a total of 99 purchase orders, but for each of these there are estimates available. These estimates are either delivered by procurement and estimating departments, or estimated on the basis of the ECC project (Sub-Section 6.2.3). Each of these purchase orders has a number of listed suppliers, a supplier country, and an estimated value. In Section 4.5 countries that are significantly different from one another, with respect to quotation values, are shown. These price differences will be taken into account for the creation of dummy quotations.

On the basis of quotation values of the ECC project, the spread of the quotation values for each purchase order is determined. This is determined by firstly calculating the difference in minimum and maximum value of all quotations for each single purchase order. Secondly, this difference is divided through the average of all quotations for a single purchase order. When this is done for each purchase order, the average of the spread for all purchase orders is taken by dividing the summation of spreads by the total number of purchase orders (N). This is shown mathematically in equation (15).

$$Spread = \sum_{n=1}^{n=N} \frac{\left(\frac{MAX(PO_n) - MIN(PO_n)}{AVERAGE(PO_n)}\right)}{N} \quad (15)$$

Note that in this process the purchase orders with only 1 quotation are ignored. The average spread for quotations of all purchase orders of the ECC project is 53%. For simplicity this is rounded to 50% for the creation of dummy quotations.

The dummy quotations will be generated according to their country and the corresponding price differences among countries. In Section 4.5 it is shown, there are 5 groups of countries that are significantly different from one another, with respect to quotation values. Combining that outcome with the average spread for quotations one can evenly distribute the countries 'quotation rankings' over the spread of 50%. This is shown in Figure 62. There are 5 groups of countries, therefore, the spread is divided in 5 different ranges. Each range overlaps half of the range of its neighboring country group, to mimic some price competition among countries. Using these ranges, dummy quotation values are randomly generated using a uniform distribution. For all other countries (countries which have no expensiveness ranking) with estimated costs for purchase orders, values are randomly generated over the entire range (75%-125%), using a uniform distribution. The sourcing sheet is programmed in a way that each time a change is made in the sheet, or the excel sheet is opened, a new set of random values is generated according to the specific spread of quotations per country.

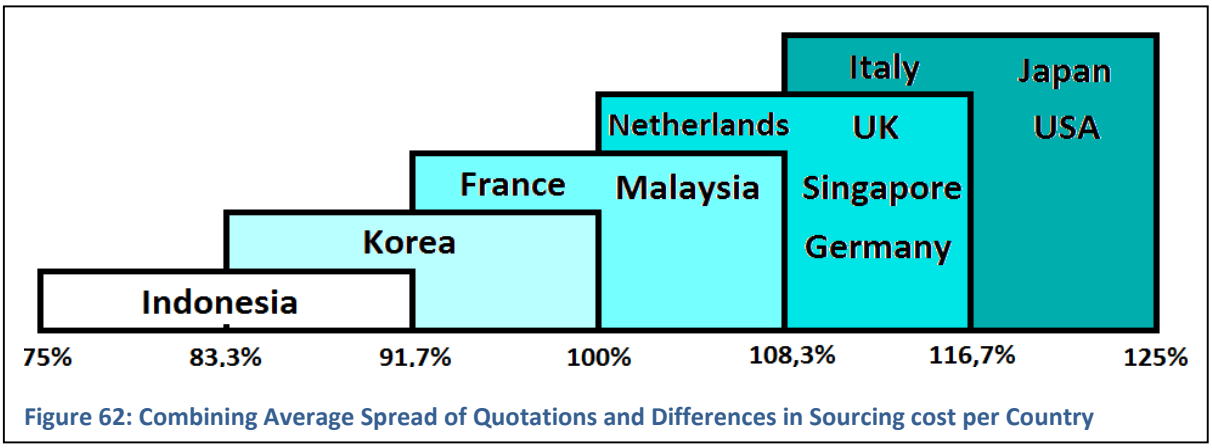

Figure 62: Combining Average Spread of Quotations and Differences in Sourcing cost per Country

6.4 TRADE FINANCE ESTIMATES

All purchase orders have listed suppliers, supplier countries and quotation values. The next step is to determine the trade finance input for the NKNK project. The data is used from the questionnaire on trade finance, discussed in Sub-Section 5.4.3. In this questionnaire, conservative and optimistic estimates are given, but only the conservative estimates are used in the simulations. In this way it is tried to avoid underestimation of the sourcing costs. All five ECA countries are included in the preliminary estimation model.

It is stated in the outcome of the questionnaire that there is no cap on the country budgets. Minimum domestic content, and maximum Russian content are given in the questionnaire. The maximum Rest of World (RoW) Content is determined by 100% minus the minimum domestic content requirement. Note that the sum of all minimum and maximum content can be higher than 100%, but it is not allowed to reach the maximum percentage of Russia and RoW at the same time. For example if the maximum of RoW content is used for a single ECA country, the maximum Russian content available for sourcing is zero.

The financial costs need to be calculated for each ECA. However, the discount rate and interest rates of ECA countries are not available. The term of the loan, the number of repayments per year, and the interest rate differential of SECA (when compared to other ECAs) is known. Equation (11), explained Section 5.4.2, is applied to calculate financial costs of SECA. In these calculations a discount rate of zero is used and the interest rate differential is used as APR. This results in an interest rate coefficient of 1.075. Therefore, its corresponding financial costs is 7,5%. This is added to the ECA premiums, which are estimated to be equal for all ECAs. The input in the sourcing sheet for the ECA countries is summarized in Table 22.

Table 22: Summary Trade Finance Input

ECA	Min. Dom. Cont.	Max. Russ. Cont.	Max. RoW. Cont.	Financial Cost
Atradius	20%	15%	80%	7,6%
Euler Hermes	51%	15%	49%	7,6%
SACE	30%	15%	70%	7,6% + 7,5%
KSURE / KEXIM	100%	None	None	7,6%
JBIC / NEXI	100%	None	None	7,6%

This trade finance data is used as an input for the cost optimization simulations described in the next Section.

6.5 SIMULATIONS OF PRELIMINARY SOURCING COST OPTIMIZATION

The sourcing sheet now contains, a number of suppliers, supplier countries, and quotation values for each purchase order. In addition to this, there are inputs for trade finance. The total sourcing costs can now be estimated. However, it is challenging to optimize the sourcing cost, i.e. finding the least expensive solution for total sourcing cost. To solve this linear optimization problem a mathematical optimization model is developed to optimize total cost of sourcing. This model is described in wording in Sub-Section 6.5.1. A detailed mathematical formulation of the optimization problem can be found

in APPENDIX A. It is programmed in mathematical optimization software (AIMMS). The Monte Carlo method is applied using the optimization model in Sub-Section 6.5.2. The output of the Monte Carlo simulations is a probability distribution of optimized outputs, EAC budgets used, and budget flows to other countries.

6.5.1 COST OPTIMIZATION MODEL.

The cost optimization model is developed in line with this thesis. During the internship, there was a comprehensive cooperation with a consultant from CQM (Consultants in Quantitative Methods). The consultant was provided with a conceptual model, in both business and mathematical formulations. The consultant has done all of the mathematical programming, and received continuous feedback on the development. Some minor changes in scope had to be made, but the initial conceptual model proved to be correct. During the writing of this thesis the model was programmed from scratch, to a fully functional optimization model. The model is submitted to numerous tests, to conform the validity of it. After all flaws in the model were fixed, the model was approved by CB&I through an official acceptance test.

The optimization model is programmed in AIMMS (Advanced Interactive Multidimensional Modeling System), which is software for modeling and solving large optimization problems. AIMMS allows abstract mathematical modeling, which is very convenient when considering the large numbers of parameters in the model. The optimization model should easily be able to handle 500 purchase orders with an average of 5 quotations per purchase order. All input parameters will be delivered through an excel sheet, which is referred to as the 'sourcing allocation table'. The sourcing allocation table is imported into AIMMS, where it is stored in the same format as the input file. The optimal solution, the allocation of a single quotation for each purchase order to a supplier that will have the lowest overall sourcing costs, will be exported to an excel output file.

The objective of the optimization model is to select for each purchase order a quotation, while satisfying the budget constraints and minimize the overall sourcing costs. The mathematical formulation of the model is shown in APPENDIX A. The model incorporates the following restrictions, in business wording:

- Select for each purchase order exactly one quotation and choose an ECA country from which this quotation is financed.
- Do not exceed the maximum budget of an ECA country.
- Spend at least a certain percentage of the total expenditure of an ECA country within that country. (Domestic financing costs do not count as domestic expenditure)
- Spend at most a certain percentage of the total expenditure of an ECA country in Russia.
- Spend at most a certain percentage of the total expenditure of an ECA country in Rest of the World. Rest of the World being all countries not considered an ECA country or Russia.
- The part of the budget of an ECA country that is spent within that ECA country is at least as big as the part of that budget spent in any other country.

The objective is to minimize costs, which consists of the following two elements

- Finance cost based on an interest rate coefficient per ECA country.
- Quotation values per purchase order.

The optimization problem and its mathematical equations are relatively easy to state. There will be a finite, but large, number of possible solutions. Simply calculating all possible outcomes and select the lowest value as the optimal solution will not be possible, due to the exponentially increasing number of possible solutions. E.g. consider 500 purchase orders with 2 different suppliers. The number of possible solutions will be, as it are binary variables, 2^{500}. This is a number so large that it cannot even be computed by a standard calculator. It requires an algorithm that searches the complete space of possible outcomes to select the optimal solution, but without calculating every possible outcome. A widely used tool is the Branch and Bound algorithm, which enables to search parts of the solution space only implicitly. It is basically a tree search which generates a set of ever improving solutions. This algorithm discards en masse sets of solutions that cannot have a lower value than the best solution found so far. Hereby it seriously reduces the number of possibilities, and significantly reduces the calculation time.

When finalizing this thesis, an additional function was added to the model. The results of manually performed Monte Carlo simulations where received very well. A downside of these simulations was the effort that had to put into this boring repetitive task. The additional function in the model is an automatic Monte Carlo simulation. In these simulations the input parameters of the dummy quotations change for each run, in both country and value, according to the derived statistics in the previous chapters. With each new set of generated values the model is run according to the restrictions stated in this section. Its optimal solution is stored. The Monte Carlo allows predefining the maximum deviation of dummy quotation values from the mean, and a choice can be made between a normal and a uniform distribution. Also the total number of runs for each Monte Carlo simulation can be set. However, due to time restrictions, only manually performed Monte Carlo simulations are incorporated in this thesis.

6.5.2 MONTE CARLO SIMULATIONS

The sourcing sheet contains numerous random values for quotations and random countries for (unknown) suppliers. Therefore there is no definitive solution to the optimization problem, but rather a set of outcomes. A Monte Carlo simulation is done. This is done by importing the sourcing sheet in AIMMS, calculating the optimized value, and summarizing the results. The simulation is done 100 times. It is desired to have a larger number of simulations to acquire more robust results, but the process is not automated yet.

Out of 100 excel sheets containing output data of the sourcing optimization model, for each set of randomly generated data, a minimum and a maximum total optimized sourcing cost value was retrieved. On the basis of these values ranges were determined. Using excel, the frequency in which the total optimized value outputs fell within a specific range was determined. This output of the Monte Carlo simulation is shown in Figure 63. All outputs are in a range between 1,170 and 1,240 million USD. The mean of the simulations is around 1,204 million USD. Meaning that all values of the Monte Carlo simulation fall within a -3% to + 3% of the mean. This relative small difference is more substantial in absolute numbers, with a total spread of 70 million USD. If the optimization is done without randomly generated values for quotations there is only one outcome: 1,258 Million USD. It can be concluded that using random values for quotations in optimization always reduces the estimated sourcing costs. This is not surprising as the random generation of quotations values results in lower as well as higher quotations, but the optimization process only selects all lowest quotations per purchase order, as long

as there is budget available in the country of those lowest quotations. With no caps on ECA country budgets, and low requirements for domestic content, the optimization model is often able to select the cheapest quotation available (regardless of the supplier country). Having strict budgetary constraints might lead to a different result.

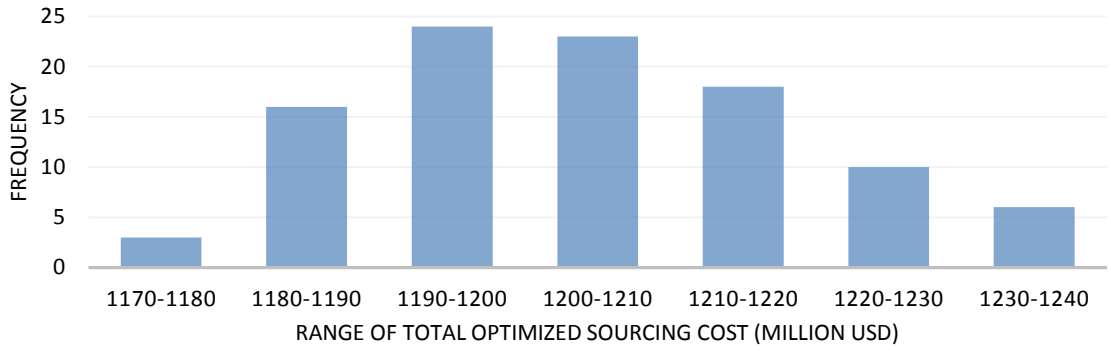

Figure 63: Range of Optimized sourcing Costs and its Frequencies

More important is, in the context of the research, where budget is most likely needed. Budgets are settled in early stages of a project, and the resulting budgetary restrictions could seriously increase total sourcing costs, when not estimated correctly. For example, due to a budgetary mismatch, sourcing cannot be done in a country where the least expensive quotations are available. Ranges of expenses in countries are retrieved from the Monte Carlo simulations. This is done using the same counting methodology as for Figure 63. These ranges and their corresponding frequencies are shown for Netherlands and Rest of World in Figure 64 and for the other ECA countries and Russia in Figure 66. These are not shown all in the same figure for practical reasons (large absolute differences in total expenses). The reason for the expenses within the Netherlands being significantly higher than all other ECA countries, is that a single source purchase order of 190 Million USD is sourced in the Netherlands. Having such a large values quotations in an ECA country requiring only 20% domestic content, means that there is 760 million available to source in all other countries (except for Russia which has a maximum of 15% Russian content). A large single source purchase order in ECA country the Netherlands provides slack for spending in Rest of World or other ECA countries, where there is a high chance of finding less expensive quotations (the Netherlands is significantly more expensive than

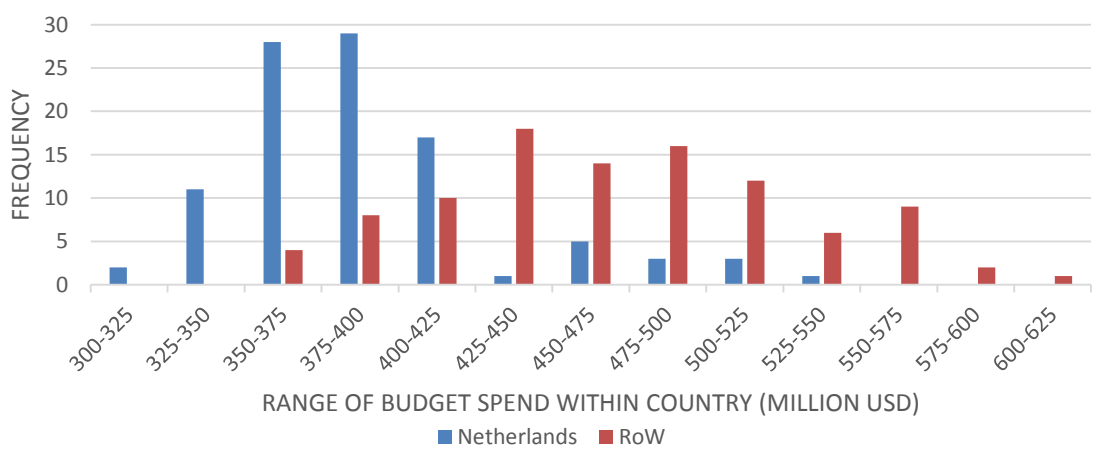

Figure 64: Range of Optimized budgets spent within NL & RoW and its Frequencies

average). The range of budget spend in the Netherlands is quite large (300-550 Million USD). It remains relatively uncertain how much will be spent in the Netherlands. One can decrease this uncertainty by stating that there is a 70% chance that the budget spent in the Netherlands will be between 350 and 425 million dollars, by summing up the most frequent ranges. Also the spread of what is spend in Rest of World is large, ranging from 350 to 625 million USD. To reduce this uncertainty a little one can say 60% of this spread falls between 425 and 525 million USD, but one should be careful relying heavily on the estimate.

The distribution of budgetary expenses from ECA country the Netherlands among other countries, Russia and Rest of World is shown in Figure 65. The figures shown all are an average of total number of runs of the Monte Carlo simulation. It can be concluded that the Netherlands does not near its minimum constraint of 20% domestic content, as a total fraction of 40% of the ECA budget from the Netherlands is spent in the Netherlands. 'Other ECA' involves predominantly Italy and Germany, as Korea and Japan have 100% domestic content constraint, therefore ECA budget from the Netherlands flows in these ECA countries only sporadically (randomly assigned by the optimization model). A substantial amount flows from ECA country Netherlands to Rest of World (40%), being all non-ECA countries and non-Russian. Eight percent of all contract value of the Netherlands is Russian content.

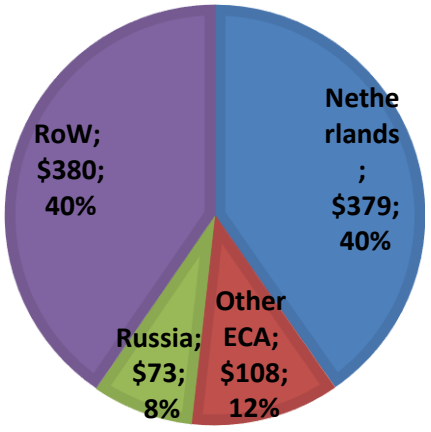

Figure 65: Budgetary Flows Netherlands

(Absolute figures in Million USD)

The amount spent in all other ECA countries and Russia is shown in Figure 66. The most convincing result is seen for Japan, for which all simulations give an estimated expense between 75 and 100 million USD. The second clearest result is seen for Italy, almost 80% of all simulations fall within the range between 50 and 75 million USD. For Germany 75% of the estimated expenses within that country fall between 100 and 150 million USD. For sourcing in Korea the estimated expenses will be somewhere between 75 and 200 million USD. The most uncertain result is for Russia, the only thing that can be said for Russian expenses is that is estimated to be above 25 million USD and below 200 million USD.

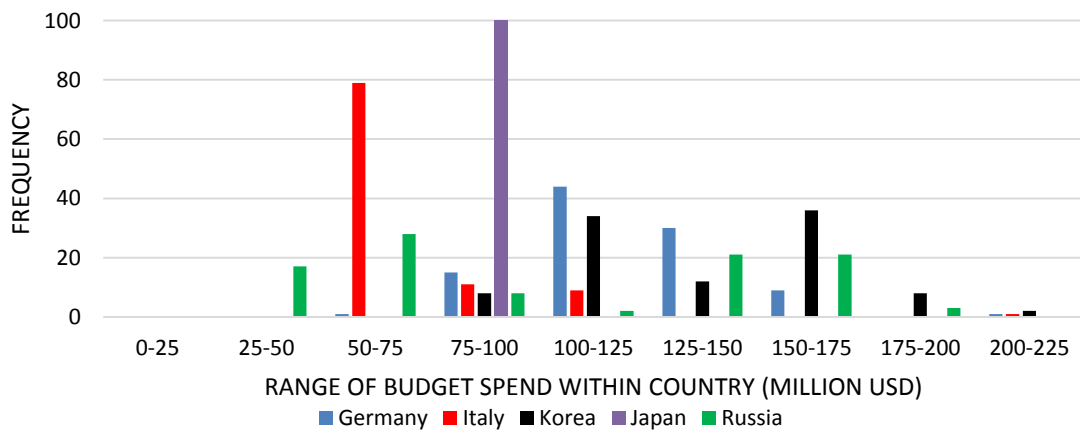

Figure 66: Range of Optimized budgets spent within countries and its Frequencies

To analyze the ECA flows (with respect to domestic spent, Russian spent and Rest of World spent) Japan and Korea can be disregarded as they do not allow foreign content, meaning that there is no ECA budget flowing out of these countries. In the model there was not a single case of ECA budget used in Italy, as its financing costs were twice as high as for all other ECA countries. In combination with sufficient available budget from other ECA countries (Netherlands and Germany), there was in 100 simulations never a necessity to use expensive Italian ECA budget, as part of the optimized outcome. The analysis of budgetary flows can therefore only be done for Germany. This is shown in Figure 67, where the average is taken of the Monte Carlo simulations. A total fraction of 52% of ECA budget from Germany is also spent within Germany, satisfying the minimum restriction of 51% domestic content. This does not leave much slack, therefore one must be careful fixing the German budget strictly. The amount spent in other ECA countries and Rest of World is similar (in relative terms) to what was seen for the Netherlands, but the Russian content in German loans is significantly lower, when compared to the Netherlands.

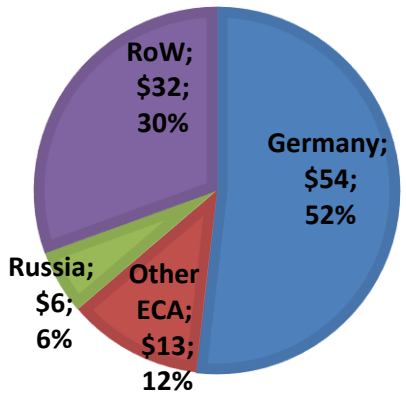

Figure 67: Budgetary flows from Germany

(Absolute figures in Million USD)

All estimated ECA country budgets needed for financing the sourcing expenses in the NKNK project are summarized in Figure 68. For each ECA country budget the average is taken from all 100 simulations. It is estimated that 78% of the total of all ECA financing will come from the Netherlands. In absolute amounts this is 940 million USD. There are 2 reasons for this. The most important reason is the flexible position of the Netherlands regarding the required minimum domestic content (20%). This allows a relatively large amount of Dutch ECA budget to be used in less expensive countries. The second reason is the Dutch single source purchase order of 190 million USD, which in turn provides possibilities for spending in the Rest of World, Russia and other ECA countries. Japan and Germany are estimated to have similar ECA country budgetary needs, both 9% of the total amount of financing needed. The difference between the two is that, of German ECA budget 52%, is spent within Germany where all ECA budget of Japan is spent within Japan (due to minimum domestic content 100% restriction). The smallest ECA country budget needed is estimated to come from Korea, which accounts for only 4% of the total of financing needed for the sourcing of the NKNK project.

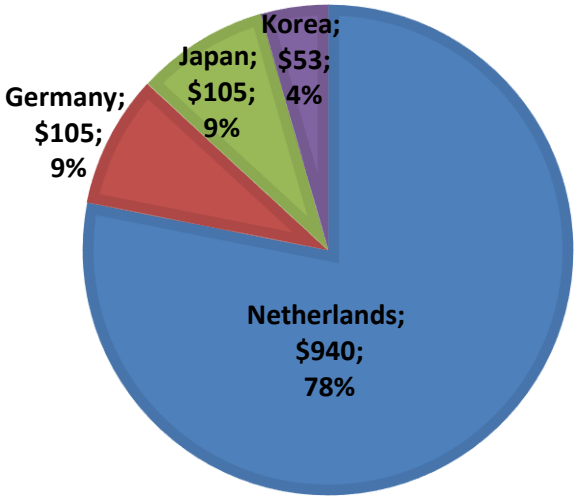

Figure 68: Summary estimated ECA Country budgets

(Absolute figures in Million USD)

6.6 CONCLUSIONS

In this Chapter a method is suggested for preliminary cost estimation. These cost estimations are based on a souring allocation table. This souring allocation table contains the total number purchase orders, quotation values, cost estimates, dummy quotations, suppliers, supplier countries, cost differences among countries, ECA country budget constraints, and ECA financial costs. As there are numerous random values in the cost estimations, a Monte Carlo simulation is done. The output of these simulations are probability distributions (represented by frequencies of absolute values falling within a specific range) with respect to the total sourcing cost, the total expenditure in each country, and the budgetary expenses of each EAC country.

The preliminary cost estimation method starts with evaluating what data is readily available as an input, with respect to the number of suppliers and supplier countries. Data that is not readily available can be estimated in 2 different ways on the basis of a reference project. The number of suppliers per purchase order with missing data will be selected on the basis of the average selected number of suppliers for that purchase order category. The suppliers with an unknown supplier country will be estimated on the basis of descriptive statistics on each purchase order category. The missing supplier countries will be randomly generated, by using the distribution of potential suppliers among countries per purchase order category.

The second step is to estimate costs of purchase orders, for which no live estimates are available. This is done per purchase order by using the order of magnitude method, in which the costs of each purchase order will be based on the costs of a similar purchase order in a similar project. This capacity factored estimate will be indexed to accommodate the inflationary impact of time, using the Chemical Engineering Plant Cost Index.

When the first two steps are undertaken, one can create dummy quotations. These dummy quotations take significant sourcing cost differences among countries into account. Countries are divided into different groups, from least expensive to most expensive. The spread in which quotations vary is determined by analyzing all quotations values of the reference project. The spread is combined with the different country cost categories to randomly generate quotation values for potential suppliers, taking the cost estimate of the purchase order and the country of manufacturing into account. These dummy quotations will be a direct input in the preliminary estimation model.

Trade finance estimates will used as a direct input in the optimization model. This input contains budgetary constraints per ECA country. These constraints are: the total budget available, minimum domestic expenditure, maximum Russian expenditure, and maximum rest of world expenditure. Also the financial cost of ECA countries are included in the model through an interest rate coefficient.

A Monte Carlo simulation is done on the output of the optimization model, using the souring allocation table as an input. The output consists of a probability distribution of the total optimized value and a probability distribution of the expenditures within each country. The output also contains an average distribution of ECA budgetary flows, with respect to other ECA countries, Russia, and all other countries.

CHAPTER 7 CONCLUSIONS AND RECOMMENDATIONS

In this Chapter the findings of the thesis are summarized and recommendations are given. Conclusions, which should give an answer to each central research question, are stated in Section 7.1. The managerial recommendations are given in Section 7.2. The limitations of this research and suggestions for further research are discussed in Sections 7.3 and 7.4

7.1 RESEARCH FINDINGS

The research findings are summarized in a structured manner. In this way findings are shown per central research question, stated in Section 1.5.

7.1.1 CENTRAL QUESTION 1

What determines the amount of potential suppliers selected in sourcing for large projects?

There are multiple restrictions in selecting potential suppliers for a project. Firstly, suppliers can only be selected and inquired for a bid, if they are stated in an 'Approved Vendor List'. Secondly, ECA involved financing limits to a certain extent the amount of budget available in each country. Therefore, selecting suppliers in a country where probably no budget is available, is a waste of effort. Thirdly, the increasing administrative burden in selecting larger numbers of suppliers poses limitations. Through a comparison on descriptive statistics on suppliers in two very similar projects, but with different project contexts, the effects of these limitations are determined. It is shown through descriptive statistics that the amount of selected suppliers differs significantly per purchase order category. Piping materials have the highest, and equipment materials the lowest, number of selected potential suppliers per purchase order.

In ideal cases, a buyer would like to inquire as much suppliers as possible. Doing so will increase its chance of receiving the lowest bid in the market. Under high levels of competition among buyers, suppliers are less likely to respond to a bid inquiry. Consequently, less attractive bids are received. Therefore, despite the restrictions on selecting suppliers, the degree of competition is a determinant for the amount of selected suppliers. Through a linear regression technique, it is shown that the perceived level of competition determines to some degree the number of selected potential suppliers. The perceived level of competition is acquired through questionnaires with exports. By combining the level of competition and the number of selected suppliers per purchase order category, a significant correlation is shown between the two. A high degree of competition on the supply and the demand side is positively correlated to the number of selected suppliers.

7.1.2 CENTRAL QUESTION 2

What is the impact of project context on the selection of suppliers, with respect to supplier countries?

By comparing descriptive statistics on the NKNK project and reference project (ECC) it was explored whether the project context is important in selection potential suppliers. The ECC project was situated in Singapore and the NKNK project will be executed in Russia. This was reflected by selecting a larger number of potential suppliers in the project region. The Netherlands has an important share in both projects, indicating the importance of the location where the engineering and design of the project to

be undertaken is done. There is a bias towards selecting suppliers in the region (Western Europe) of the office where the engineering is done for both projects. Germany is a large potential supplier for the NKNK project, where it had only a minor role in the ECC project, indicating the importance of budgetary constraints in a project.

7.1.3 CENTRAL QUESTION 3

What are the sourcing cost differences among countries?

There are sourcing cost differences, because of multiplicative macroeconomics factors affecting the quotation values, which are determined through a literature reviews. Economic-, infrastructural-, labor-, supply based-, and political factors play a role in sourcing costs differences. Using a regressions analysis on quotation values on data from a reference project, and subsequently determining whether there are significant differences in these quotation values among countries, a rich set of significant differences (74) in quotation values between countries is obtained. The least expensive country is Indonesia, followed by Korea. France and Malaysia are moderately expensive. More than average expensive countries are Germany, UK, Singapore and the Netherlands. The most expensive countries are Italy, Japan and the USA.

The cost ranking of countries was substantiated with macroeconomic indicators. The indicators are a measure of the competitiveness of countries. Twelve macroeconomic indicators per country were reduced to two factor scores per country, using principal component analysis. Using these factor scores, and combining the countries cost categories and the descriptive statistics, it could be determined in which country one should source for each specific purchase order category. For low tech special equipment, and low tech static equipment, one is most likely to receive the least expensive bids from Indonesia. The second least expensive bids in low tech static equipment can be expected from Malaysia, where cables are also less expensive than other countries. Korea offers a broad range of static equipment and is especially competitive in heat exchangers, columns, and reactors. For rotating equipment, instrumentation, piping, and all electrical equipment other than cables one should inquire suppliers in the Netherlands, Germany and the UK in order to receive the most competitive bids. One should avoid Italy, USA, and Japan as they are unlikely to offer competitive bids for all purchase order categories.

7.1.4 CENTRAL QUESTION 4

What is the impact of Export Credit Agency involved trade finance on total sourcing costs?

The appropriate mechanism to qualitatively model the role of Export Credit Agencies, in trade finance for large industrial projects, is buyer credit. Buyer credit is the mechanism used with medium- to long-term trade transactions. ECAs are involved by issuing insurance, for defaults, directly to the exporter's bank. ECAs are also involved in buyer credit by offering a precompletion risk facility to the exporter. In order to quantitatively model financing cost of ECAs, the financing costs can be divided in a capital investment period and a repayment period. It is shown that differences in financing costs between ECA countries can be modeled through an 'interest rate coefficient', which is independent on the total value of the loan. The ECA premium can simply be rolled over in the loan, and be added to the interest rate coefficient, to take it into account. In addition to the financial costs of ECA countries, there are budgetary constraints. These include the maximum budget that is available per ECA country, a

minimum domestic expenditure, a maximum Russian expenditure, and a maximum rest of world expenditure.

7.1.5 CENTRAL QUESTION 5

How can predictions be made for the NKNK project on the optimized total costs of sourcing, ECA budgets needed, and the sourcing expenses in different countries?

The method starts with evaluating which data is readily available as an input, with respect to the number of suppliers and supplier countries. Data that is not readily available on the number of suppliers and supplier countries can estimated on the basis of a reference project. An alternative method to estimate the number of potential suppliers is through the correlation between perceived competitions and amount of selected potential suppliers. The second step is to estimate costs of purchase orders, for which no live estimates are available. This is done by using the order of magnitude method and indexation. Thirdly, estimates for the terms & conditions of Export Credit Agencies can be obtained through a questionnaire with a consulting bank in trade finance. Through combining dummy quotations, sourcing cost optimization, and Monte Carlo simulations a range of optimized values can be obtained for total sourcing costs, expenditures per ECA country, and expenditures within countries.

7.2 MANAGERIAL RECOMMENDATIONS

The managerial recommendations are summarized in this Section. Firstly, strategic sourcing strategies are suggested. Secondly, a method to quantitatively compare financing costs of different ECA countries is discussed. Thirdly, a method is suggested to make preliminary predictions on optimized sourcing costs, which combines live data and statistics. All of the recommendations aim at one thing, and one thing only: Reducing overall costs of the sourcing process.

7.2.1 STRATEGIC SOURCING STRATEGIES

Importance of strategic sourcing is underlined in this thesis. Sourcing strategies are suggested for different levels of competitions. Managers could apply the following strategies, when facing less than average imperfect competition on the supply side. The effectiveness of the strategies suggested depend the market power of the buyer:

- Divide the demand into demand tranches and spread these tranches in different time periods. The time periods should be long enough to avoid suppliers reaching their capacity constraints.
- Divide the demand into demand tranches and spread these tranches over different geographical regions, which have little interaction, to avoid each region reaching its capacity constraints.
- Use a single sourcing strategy in order to create all-out competition between suppliers.

When facing more than average competition on the supply side the following strategies are suggested:

- If an industry of suppliers nears its capacity constraints, do not share information about the future demand for goods & services.
- If an industry of suppliers does not face capacity constraints, share information about future demand for goods & services.

The aim of applying these sourcing strategies is to reduce sourcing costs per purchase order. However applying these sourcing strategies have serious limitations. Due to the highly customized nature of the business, a multiple sourcing strategy is not appropriate for the majority of purchase orders. Dividing purchase orders in tranches could backfire, resulting in latency, higher costs, and logistical nightmares. Most efficient is still to evaluate a set of bids, and select the most attractive one. This single source strategy should always be applied a single purchase order, with the exception of commodity items.

7.2.2 MODELLING OF TRADE FINANCE

In this thesis a method is developed to quantitatively compare financing costs of different Export Credit Agency countries, which have different terms & conditions. The quantitative comparison is done on the basis of the term of the loan, the number of repayments per year, the start of the repayment period, the interest rate, the ECA insurance premium, and a discount rate. In this method financing costs of different countries are compared through an interest rate coefficient, which is independent on the total value of the loan. The aim of this interest rate coefficient is to easily determine the least expensive loan option for projects. This interest rate coefficient could also be used in a mathematical sourcing optimization model. This new method is approved by a bank consulting in trade finance.

7.2.3 PRELIMINARY COST ESTIMATION OF PROJECTS

In this thesis a method is developed, which combines live data and statistics of reference projects, to make predictions on sourcing costs. It is not a new field of study to estimate the total sourcing costs of projects. It is a new study to determine probabilities of where (and to what extent) sourcing budgets are needed, while taking advantage of known sourcing costs differences among countries specific for each purchase order category. The method developed includes randomly generated dummy quotations as inputs in a sourcing optimization model. This optimization model can incorporate trade finance related costs and budgetary restrictions. Using Monte Carlo simulations, probability distributions can be derived on the overall costs of sourcing, the expenses in different countries, and the ECA budgets needed (including their budgetary flows to other countries). One could take advantage of these probability distributions by fixing ECA country budgets in an early stage of the project, but enabling to have an optimized sourcing process (i.e. to always have sufficient budget in a sourcing country for a purchase order that is part of the optimized sourcing plan). The goal of this method is to increase the probability of reducing overall sourcing costs.

7.3 RESEARCH LIMITATIONS

The most important research limitation is, it cannot be tested whether the ECA country budgets will lead to an optimal sourcing outcome for the NKNK project. As it is an ongoing process, the method will not be proven to be successful until the procurement phase of the project is completed. It is encouraging that the estimate made on the total costs, is similar to what is stated by the estimating department of CB&I. The estimates delivered by the estimating department are on a higher level, not on a purchase order level, and therefore estimates cannot be validated on a low level. Moreover, these estimates do not state anything on the distribution of costs among countries. Despite these limitations, the project owner was satisfied and impressed with this approach.

Another important limitation is the outdated data that is used to determine significant cost differences among countries. These countries were proven to submit statistically different quotations values in

2006, but these statistical differences are not necessarily still valid at this moment in time. For this reason this data is substantiated with macroeconomic theory and descriptive statistics on suppliers. Although the conclusion drawn from this analysis seems to be correct, the amount of evidence is relatively minor.

The research was not able to determine exactly the differences between the terms & conditions of ECA countries. Through a questionnaire with a bank, only estimates of these terms & conditions were obtained. Therefore, the Monte Carlo simulations had conservative estimates for trade finance as an input, possible not reflecting the real terms & conditions that will be set for the project.

The generation of dummy variables is done, for the sake of simplicity, on a uniform distribution based on the spread of quotations values and the costs ranking of countries. Possibly, this does not accurately predict the real world, as distributions could have different means and standard errors, and are certainly not uniformly distributed.

7.4 SUGGESTIONS FOR FURTHER RESEARCH

A relationship is derived between macroeconomic factors, sourcing cost differences among countries, and descriptive statistics on suppliers. In this way it is explained why sourcing cost differences occur, and for which type of purchase order they occur. It cannot be established with certainty that sourcing cost differences be predicted on the basis of these macroeconomic factors, as there is only minor evidence (i.e. only a single project is analyzed). It must be tested whether the conclusions drawn still hold in this moment in time. This can be done by repeating the process described in Chapter 4, but with the quotations received for the NKNK project, and macroeconomic indicators reflecting the dates of these quotations.

The method of estimating total sourcing costs can be extended towards a method in estimating total overall costs. Although, such a method already exist, as indicated in Sub-Section 6.2.2, there is no method that includes multi ECA financing estimations of total installed costs. Research must be done in order to further extend this model into a more complete predictive model. This further research should aim at including transportation and construction costs.

In this thesis the distribution of quotation values, to generate dummy quotations depending on country cost ranking, are assumed to be uniform. Accurate distributions of quotation values of each possible sourcing country need to be established in order to generate dummy variables that reflect the real world more accurately.

CHAPTER 8 REFLECTION

This chapter discusses the lessons learned during the research, exemplify important choices made, and to reflect on methods used. The results and personal experiences from the past five months are reflected in a chronological like story. It can be concluded that coincidences had a huge impact on the structure of the thesis, and until the very end it was not sure how it would look like exactly and what the end result would be.

When I initiated the internship at CB&I, my thesis subject could not have been any clearer. Develop a mathematical optimization model in order to calculate the lowest possible value out of a set of purchase orders and corresponding quotations, while taking budgetary constraints and financial costs of ECA countries into account. During the writing of my research proposal, CB&I had contracted a consultant in order to do the mathematical modelling. My task would be to supervise and cooperate with this consultant, and in line with this, developing a predictive model for sourcing costs among countries. Consequently, the subject of my thesis had to be changed last minute, and so did my research proposal. As I already had put an enormous amount of effort in formulating the mathematical optimization model, I have not been able throughout this thesis to let it go. My first supervisor, Scott Cunningham, has indicated multiple times that involving this mathematical model is potentially harmful. It could weaken my thesis.

After the research proposal had been approved, I had only little contact with other employees in the office of CB&I. I was situated in a separate room in the outermost corner in the building, and I have hardly been introduced to employees within CB&I. After complementing the thesis with some general theory on sourcing strategies, it was time to put these to the test. To gain more understanding on the sourcing process within CB&I and to improve my integration within the company, I decided upon taking questionnaires with procurement managers. These turned out to be very valuable in terms of my understanding of the whole process. However, it was hard to fully integrate these in the thesis. However, it did gave me results on the perceived competition in the market, the limitations on using multiple sourcing strategies, and the restrictions procurement managers face on the selection of suppliers.

Once the first version of the optimization model was working, on which I was continuously providing feedback, a testing sheet needed to be made. This sheet needed to realistically represent the sourcing possibilities in the NKNK project, in order to pass the acceptance test of CB&I. I was provided with data sheets containing a list of purchase orders for the NKNK project, including potential suppliers. Some of these purchase orders had estimates, most had not. Most had listed suppliers, some had not. None of the quotations had values, therefore, I randomly generated data for these quotations, which was uniformly distributed on the estimated values of the purchase orders. Thereby, I converted this list of purchase orders to a list of quotations with suppliers located in multiple countries. This could be used as an input for the first testing of the model. Hereby, I simultaneously had created a list in which I could easily retrieve the descriptive statistics on suppliers. Not knowing what to do with these statistics, I decided to work them out anyway, for it may be proven to be useful eventually.

In the meantime I also collected a large set of data from the reference project (ECC), which I projected to use to examine sourcing cost differences among countries. This revealed that there was a huge difference in the selected potential suppliers between the NKNK project and the ECC project. Therefore, I decided to further investigate what determined these differences, hence the research

question on project context came up. After having collected a large set of bids from suppliers, I faced the task to subject statistical tasks to it. This should reveal whether there are sourcing cost differentials among countries. Despite my Bachelor's course in Statistical Methods, and my Master's course in Quantitative Research Methods, which I both passed flawlessly, I did not have a clear view which statistical tests to use. Luckily, Scott Cunningham helped me with the selection of a suitable method: Linear regression using categorical variables.

In April, it was planned to have a set of quotation values for each purchase order. Thereby, we could do real runs for the optimization, to present to the client. This would simultaneously be regarded as an official acceptance test of the model. However, in June there still was no complete list of quotations. As the client was pushing for results, we had to come up with a solution. We came up with the idea of doing a quasi-Monte Carlo simulation on all data we could possibly retrieve. Consequently, I was forced to evaluate all data I had collected so far. The average spread of quotations could easily be calculated by using the data on bids of the ECC. By combining this spread with the significant cost differences among countries, I could generate random values based on this data. This was done for purchase orders of which we had estimates. For the purchase orders of which we had no estimates available, I could use the contract data of the ECC data I collected to determine cost differentials among countries, and apply the order of magnitude method, indexed it accommodate the inflationary impact of time. The descriptive statistics, of which until then I had no clear clue how to fully integrate these in the thesis, proved to be very valuable in generating dummy quotations for the Monte Carlo simulations.

As one of the most important research questions in the research proposal was to predict sourcing costs of countries, based mainly on macroeconomic factors, I continued in selecting macroeconomic factors, and determined a set of indicators to represent them. Scott Cunningham pointed out in advance that I could only select a limited amount of factors for a linear regression. As it was impossible to determine beforehand which macroeconomic factor was most suitable in linear regression, Scott advised on using Principal Component Analysis. Again, this was a statistical method new to me. We also came to the following conclusion. Although, there are sourcing cost differentials among countries, these are probably also related, to a huge extend, to the type of equipment that is sourced per country. Therefore, I decided upon mapping the two Factor Scores per country firstly in a two dimensional plot. Hereby, I could easily incorporate a third dimension: cost ranking of countries. As a result, descriptive statistics on suppliers could be incorporated qualitatively (i.e. what is predominantly sourced in which country), which was seemingly impossible to do by using categorical variables in linear regression. Without incorporating the equipment type in this regression, Factor Score 1 reduced the unexplained variance in the dataset to some extent, and Factor Score 2 increased this unexplained variance. It would result in approximately the same cost rankings of countries as was seen without using factor scores based on macroeconomic indicators.

Although, it is almost a certainty that a master thesis will not follow exactly the way a student has planned to do it, the circumstances leading to the completion of this thesis could seem a bit extreme. Nevertheless, I am confident I have delivered a relatively complex thesis, reflecting the high quality and demands of the Management of Technology Master Programme. I surely enriched my knowledge in statistics during this research. My skills in excel and SPSS has improved tremendously. Dealing in a highly uncertain, dynamic environment, like CB&I has demanded applying knowledge of almost every discipline the TU Delft has ever thought me. It has been a unique opportunity to test the skills I have learned. Although, I think there is still room for improvement, I am proud of the finalized master thesis.

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APPENDIX A. MATHEMATICAL DESCTRIPTION OPTIMIZATION MODEL

In this appendix the mathematics underlying the sourcing optimization model is described.

The following sets are defined:

Set	Index
Countries	c
ECA countries (a subset of Countries)	e
Purchase Orders	P
Quotations	q

The following parameters are defined:

Parameter	Range	Description
$Budget_{(e)}$	≥ 0	Total budget available in ECA country e
$QuotationValue_{(q)}$	≥ 0	Value of quotation q
$MinDomesticSpend_{(e)}$	[0,1]	Minimum fraction of ECA country e spend going to same country e
$MaxRussiaSpend_{(e)}$	[0,1]	Maximum fraction of ECA country e spend going to Russia
$MaxRoWSpend_{(e)}$	[0,1]	Maximum Fraction of ECA country e spend going to RoW
$FinancialCost_{(e)}$	≥ 0	Cost percentage incurred when spending budget from ECA country e

The following variables are defined:

Variable	Range	Description
$AllocateQoutation_{(e,q)}$	$\{0,1\}$	Value is 1 if quotation q is selected and financed by ECA country e. Value is 0 otherwise.
$BudgetFlow_{(e,c)} = \sum_{q \mid q \ from \ c} QuotationValue_{(q)} \cdot AllocateQoutation_{(e,q)}$	≥ 0	The amount of budget from ECA country e used for quotations from country c

The following constraints are defined:

Constraint	Description
$\sum_{(e,q)for\ p} AllocateQoutation_{(e,q)} = 1, \forall p$	For each purchase order p one quotation q is selected and allocated to an ECA country e
$\left(1 + FinancialCost_{(e)}\right) \cdot \sum_{c} BudgetFlow_{(e,c)} \leq Budget_{(e)}, \forall e$	Do not exceed the budget of ECA country e
$BudgetFlow_{(e,c)} \geq MinDomesticSpend_{(e)} \cdot \sum_{c} BudgetFlow_{(e,c)}, \forall e$	Spend at least a certain percentage of the total spend of an ECA country e within that country
$BudgetFlow_{(e,c)} \leq MinRussiaSpend_{(e)} \cdot \sum_{c} BudgetFlow_{(e,c)}, \forall e$	Spend at most a certain percentage of the total spend of an ECA country e in Russia
$\sum_{c\|c<>Russia\ and\ c<>e} BudgetFlow_{(e,c)} \leq MinRoWSpend_{(e)} \cdot \sum_{c} BudgetFlow_{(e,c)}, \forall e$	The Spend at most a certain percentage of the total spend of ECA country e in RoW. RoW is defined as all countries not e or Russia

The objective function is given by

$$Minimize: \sum_{e} \left(1 + FinancialCost_{(e)}\right) \cdot \sum_{c} BudgetFlow_{(e,c)}$$

APPENDIX B. EXAMPLE QUESTIONNAIRE: STATIC EQUIPMENT

Dear Participant,

First of all, I would like to thank you for your participation in this questionnaire. My name is Paul Jansen and I am a graduate intern at CB&I from the TU Delft. I am conducting a research project on behalf of Dorus Everwijn, Director of Sales CB&I. The research objective is to offer a predictive model for sourcing costs involving multiple ECA (Export Credit Agency) countries. Part of this research is to determine market characteristics regarding buyers and suppliers of certain goods. I have distinguished 4 main categories which consist of sub categories, in order to take the differences between different types of goods into account. The following categories are defined:

1. **Equipment**
   Static (large/small), Rotating (large/small)
2. **Electrical Materials**
   Cables, Switchgears & Transformers
3. **Instrument Materials**
   Instrument Valves, Metering & Analyzers
4. **Piping Materials**
   Bore fittings & Pipes, Valves

The following questions regard **Static Equipment**, I was advised to divide it into Small and Large Static Equipment, hence the almost duplication of questions. Please write down your name, department and title below. This personal data will NOT be published, but is merely for referencing when questions arise. The questionnaire will take approximately 10 minutes.

For questions or comments you can always contact me during office hours on (ext 2950) or by email (pajansen@cbi.com).

Kind regards,

Paul Jansen

PARTICIPANT:

FIRST NAME: _____

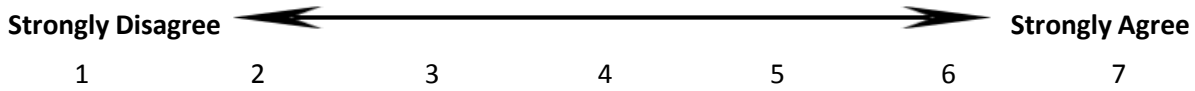
LAST NAME: _____

DEPARTMENT: _____

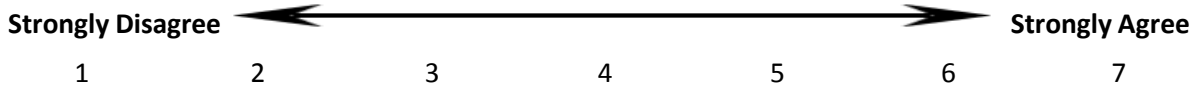
TITLE: _____

PART 1 OF 2: SUPPLY SIDE

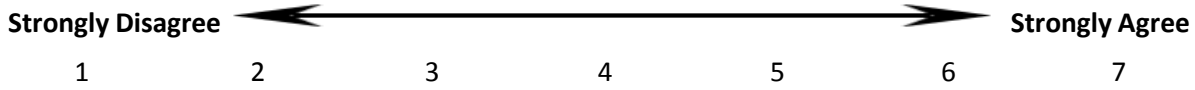
There are only very few firms for sourcing of Small Static Equipment, all well known to each other.



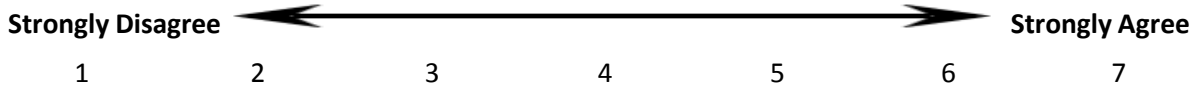
There are only very few firms for sourcing of Large Static Equipment, all well known to each other.



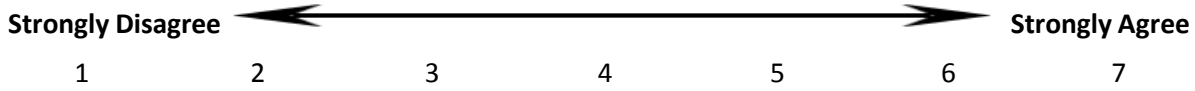
Suppliers of Small Static Equipment are open to each other about costs and production methods.



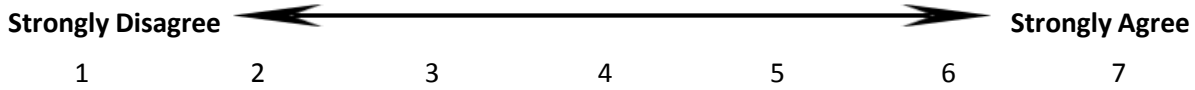
Suppliers of Large Static Equipment are open to each other about costs and production methods.



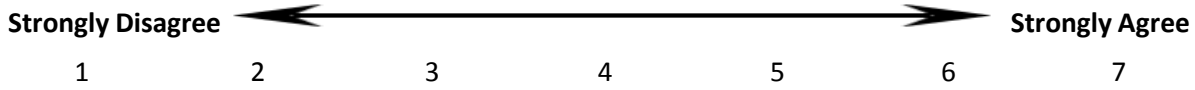
Suppliers of Small Static Equipment have similar production methods and average costs, and are thus likely to change prices at the same time and by the same amount.



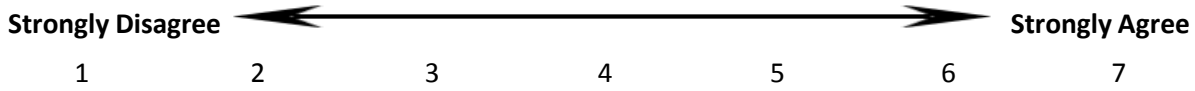
Suppliers of Large Static Equipment have similar production methods and average costs, and are thus likely to change prices at the same time and by the same amount.



Suppliers of Small Static Equipment produce similar products and thus agreements on price can more easily be reached between suppliers.



Suppliers of Large Static Equipment produce similar products and thus agreements on price can more easily be reached between suppliers.



There is a dominant firm among Suppliers of Small Static Equipment (A supplier that is significantly larger than all others and has significant market share).

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There is a dominant firm among Suppliers of Large Static Equipment (A supplier that is significantly larger than all others and has significant market share).

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There are significant barriers to entry for new suppliers of Small Static Equipment. (common barriers to entry include patents, resource ownership, government franchises and start-up cost).

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There are significant barriers to entry for new suppliers of Large Static Equipment. (common barriers to entry include patents, resource ownership, government franchises and start-up cost).

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

The market for Small Static Equipment is stable, meaning that there are no large fluctuations in demand or production costs.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

The market for Large Static Equipment is stable, meaning that there are no large fluctuations in demand or production costs.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There is no governmental policy in place for Small Static Equipment acting against collusion.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There is no governmental policy in place for Large Static Equipment acting against collusion.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

The location of the supplier of Small Static Equipment is critical in the supplier selection process.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

The location of the supplier of Large Static Equipment is critical in the supplier selection process.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There are only a few alternative markets for the goods of suppliers of Small Static Equipment.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There are only a few alternative markets for the goods of suppliers of Large Static Equipment.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

Give an estimation of the Concentration Ratio of suppliers of Small Static Equipment (Concentration Ratio is defined as the market share of the 4 largest suppliers).

Concentration Ratio

Perfect Competition ← → Imperfect Competition

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

Give an estimation of the Concentration Ratio of suppliers of Large Static Equipment (Concentration Ratio is defined as the market share of the 4 largest suppliers).

Concentration Ratio

Perfect Competition ← → Imperfect Competition

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

PART 2 OF 2: DEMAND SIDE

There are only a few buyers in the market for Small Static Equipment, all well known to each other.

Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

There are only a few buyers in the market for Large Static Equipment, all well known to each other.

Strongly Disagree ← → **Strongly Agree**

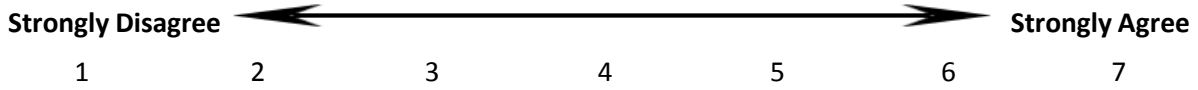
1 2 3 4 5 6 7

Buyers of Small Static Equipment are open to each other about their demand and future demands.

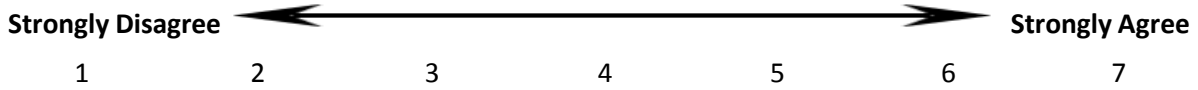
Strongly Disagree ← → **Strongly Agree**

1 2 3 4 5 6 7

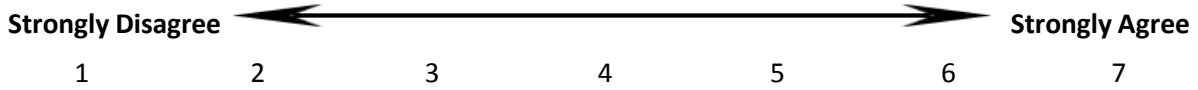
Buyers of Large Static Equipment are open to each other about their demand and future demands.



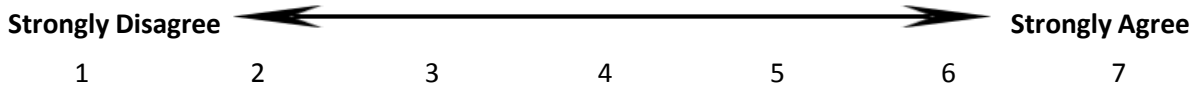
There is a dominant firm among the buyers of Small Static Equipment (A buyer that is significantly larger than others and has significant market share).



There is a dominant firm among the buyers of Large Static Equipment (A buyer that is significantly larger than others and has significant market share).



There are significant barriers to enter the buyers' market of Small Static Equipment (common barriers to entry include patents, resource ownership, government franchises and start-up cost).



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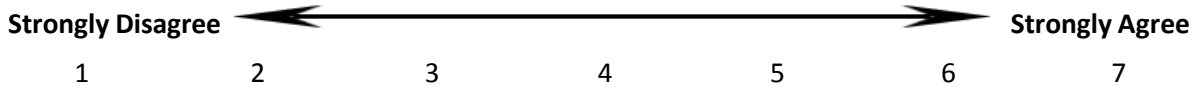
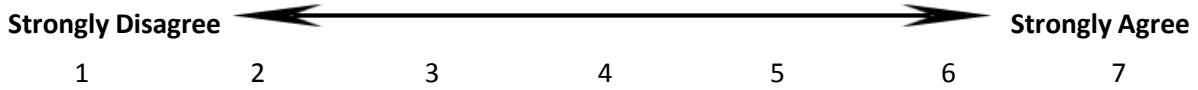


There is fierce competition for preferred suppliers among buyers for Small Static Equipment.



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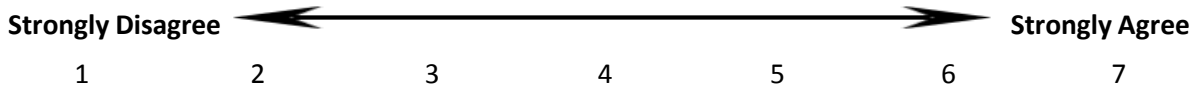
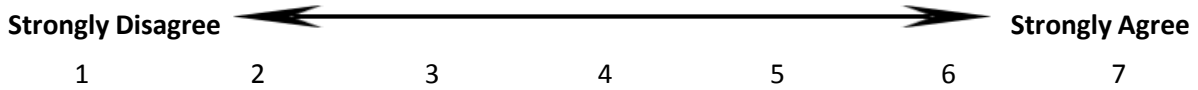
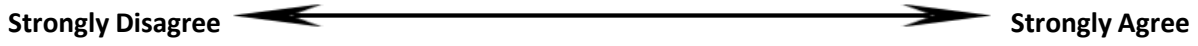


Activities of other buyers for Small Static Equipment are closely monitored.



Activities of other buyers for Large Static Equipment are closely monitored.



1 2 3 4 5 6 7

There are strong incentives among buyers of Small Static Equipment for mergers and acquisitions to gain market control.

Strongly Disagree  **Strongly Agree**

1 2 3 4 5 6 7

There are strong incentives among buyers of Large Static Equipment for mergers and acquisitions to gain market control.

Strongly Disagree  **Strongly Agree**

1 2 3 4 5 6 7

Give an estimation of the Concentration Ratio of buyers of Small Static Equipment (Concentration Ratio is defined as the market share of the 4 largest buyers).

Concentration Ratio

Perfect Competition  Imperfect Competition

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

Give an estimation of the Concentration Ratio of buyers of Large Static Equipment (Concentration Ratio is defined as the market share of the 4 largest buyers).

Concentration Ratio

Perfect Competition  Imperfect Competition

0-10% 11-20% 21-30% 31-40% 41-50% 51-60% 61-70% 71-80% 81-90% 91-100%

THANK YOU FOR YOUR PARTICIPATION!

APPENDIX C. QUASI GUASSIAN DISTRIBUTION NUMBER OF POTENTIAL SUPPLIERS

In this appendix the rejected normal distribution for the number of suppliers per purchase order is shown.

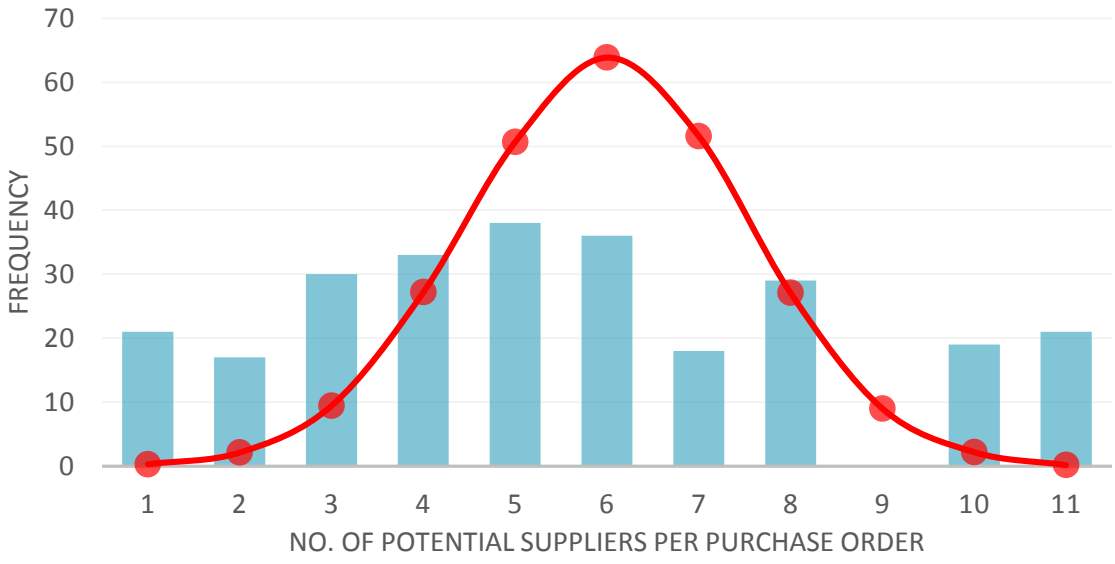


Figure 69: Frequency of Number of Suppliers for all Purchase Orders

OAO Nizhnekamskneftekhim

Sourcing Exercise: Response to CB&I Questionnaire (DRAFT)

Date: 21 June 2013

Overview of CB&I Questions

1. Please provide for the following ECA countries the minimum percentage domestic spend, and the maximum percentage spend in Russia. Percentage as percentage of ECA cover in each country.
2. Please provide absolute maximum amounts of ECA cover (if any) for each country.
3. Please provide the estimated ECA premium, as a percentage of total cover provided for each country.
4. We have modelled the interest cost as attached. It is assumed that all equipment and materials are procured in the first two years and fully paid during that period. Total time until repayment of first tranche is 4 years. Total repayment 17 equal semi-annual instalments. Please confirm this approach is acceptable.
5. Currently the model is based on a single currency. Which currencies are foreseen to be used for ECA loans?
6. What percentage of the total Equipment and Material cost will be paid from ECA loans?
7. Please confirm that ECA premium is rolled over into the loan.
8. Please explain how VAT is handled for Equipment and Materials that are procured inside Russia, paid from the Russian portion of an ECA loan.

Various countries referred to:

- Netherlands,
- Germany,
- Italy,
- Korea, and
- Japan.

ING Responses

1. **Please provide for the following ECA countries the minimum percentage domestic spend, and the maximum percentage spend in Russia. Percentage as percentage of ECA cover in each country.**

	Min. 'true' domestic content (% of contract value)	Comments:
Atradius	20%	We understand Atradius is very flexible.
Euler Hermes	51%	Assuming criteria are met as per the ING memo date 1 Feb 2013. If not, either 60% or 70% should be used, although such scenario is unlikely.
SACE	30%	As indicated in the ING memo dated 1 Feb 2013, SACE does not follow official guidelines, and does not want to formally disclose any, but for now we suggest a 30% figure is assumed.
KSURE / KEXIM	100%	This assumes that the Korean content is in the form of equipment only. There could potentially be 'foreign content', but as it is not very likely we suggest to keep it out for the purpose of this exercise.
JBIC / NEXI	100%	This assumes that the Japanese content is in the form of equipment only. There could potentially be 'foreign content', but as it is not very likely we suggest to keep it out for the purpose of this exercise.

	Max. Russian content (as % of total contract value)	Comments:
Atradius	85% x 30% = 25.5%	But not more than 30% of the export value of the contract.
Euler Hermes	85% x 23.07% = 19.61%	
SACE	85% x 30% = 25.5%	
KSURE / KEXIM	85% x 30% = 25.5%	
JBIC / NEXI	85% x 30% = 25.5%	

General comment: Under the OECD consensus rules for buyer's credit financing, up to 30% of the contract value can be added to the total eligible content. This is however a maximum figure, and it will need to be justified that such local content is indeed associated to the exported goods and/or services.
As a result we would conservatively assume that only 15% of local content can be achieved by each of the ECAs (i.e. by simply assuming that only 15% would be justifiable).

For the avoidance of doubt, the total eligible content per country is calculated as:

(Contract Value + up to 30% local content) x 85%

Some ECAs, such as EKN, apply a different methodology, where the 30% is added on top (without adjusting it to the 85%), resulting in the following eligible content calculation:

(Contract Value) x 85% + (Contract Value x 30%)

2. **Please provide absolute maximum amounts of ECA cover (if any) for each country.**

	Max. direct exposure per ECA (USD mln)	Comments:
Atradius	No cap	As most ECAs would do, if there are large non Dutch components, it is likely that Atradius will seek reinsurance with the relevant ECAs.
Euler Hermes	No cap	
SACE	No cap	
KSURE / KEXIM	No cap	
JBIC / NEXI	No cap	

3. **Please provide the estimated ECA premium, as a percentage of total cover provided for each country.**

Short answer: We suggest that we do not differentiate based on the ECA premium.

Long answer: The various ECAs have not provided any indication of an ECA premium, but we have made a few calculations based on ECAs' buyer's credit programs, using some of the tools that are available online. We do not suggest we contact the ECAs for a rushed quote now, and will therefore for now need to rely on these figures for discussion purposes. Given that the various ECAs have to follow the OECD consensus rules when offering their buyer's credit program, there have been some minor differences between premia as a result of characteristics such as categorization and loan currency.

Although the premium level will very much depend on how the ECAs would categorize NKNK, we understand the ECA premium would be in the range of 7.6% (based on a Hermes online tool and a CC2 categorisation). This could potentially be lower if the categorization would be better, to a level of for instance 6.17% or lower (based on a CC1 categorisation).

4. **We have modelled the interest cost as attached. It is assumed that all equipment and materials are procured in the first two years and fully paid during that period. Total time until repayment of first tranche is 4 years. Total repayment 17 equal semi-annual instalments. Please confirm this approach is acceptable.**

For now let's assume a 3.5+10 year tenor for the ECA loans.

5. **Currently the model is based on a single currency. Which currencies are foreseen to be used for ECA loans?**

The base case will be that all the ECA loans will be in USD. It would be good to run a scenario in which the European costs are EUR denominated and the non European costs USD denominated.

6. **What percentage of the total Equipment and Material cost will be paid from ECA loans?**

As discussed on Friday, let's try to maximize ECA eligible content.

7. **Please confirm that ECA premium is rolled over into the loan.**

Let's assume for now that this is the case for all ECAs. Our Korean ECA specialists however indicated that sometimes the premium (as well as 'interest during construction') can not be added to the Korean ECA loan amount (assessed on a case by case basis by KSURE).

8. **Please explain how VAT is handled for Equipment and Materials that are procured inside Russia, paid from the Russian portion of an ECA loan.**

ING is still exploring this, but let's assume for now that VAT is reimbursable at all times.

9. **Other**

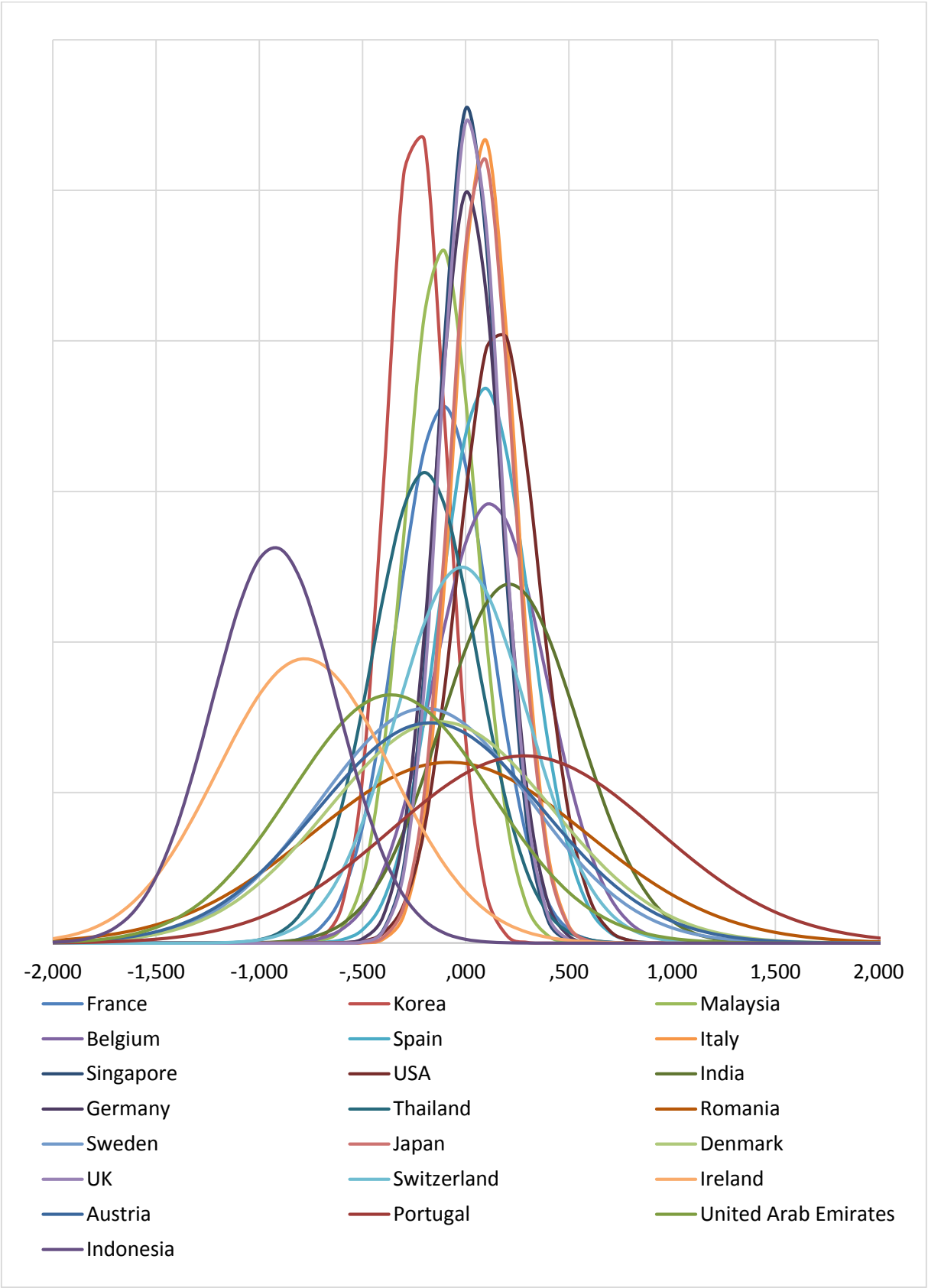
Please find below a table with the margin differentials compared to the Hermes margin (i.e. Hermes figure is equal to zero, as discussed on Friday).

	Margin differentials
Atradius	0.00%
Euler Hermes	0.00%
SACE	1.36%
KSURE / KEXIM	0.00%
JBIC / NEXI	0.00%

General Comment: We believe pricing has come down quite a bit since the market sounding in Q4 2013 (as also illustrated by an update from one of the banks last week). During the market sounding the pricing under Korean and Japanese ECA covers was not assessed, so very difficult to make a comparison at this stage. As a result we suggest to use the simplified assumption in which the margins under all ECA loans are equal, except for SACE.

APPENDIX E. PLOT OF GAUSSIAN DISTRIBUTIONS OF SPSS LINEAR REGRESSION OUTPUT

In this appendix the results of the categorical linear regression are shown graphically per country.



APPENDIX F. RESULTS SIGNIFICANCE TESTING

In this appendix, the significant results of T-distributed tests for each possible combination of countries is summarized (P value < 0.05).

Countries tested:	T statistic	Degrees of Freedom	P-value one sided
Austria vs Indonesia	2,517153208	4,25782449	0,032777674
Belgium vs France	1,864687151	10,72149112	0,045902884
Belgium vs Indonesia	6,47334051	10,23847636	3,57E-05
Belgium vs Ireland	3,394478673	2,75171785	0,038454175
Belgium vs Korea	3,431805644	6,373869119	0,006970136
Belgium vs Malaysia	2,228441493	7,080840188	0,030555621
Belgium vs Thailand	2,318548269	12,4432729	0,019434688
France vs Indonesia	5,846262186	7,823434342	0,0003165
France vs Italy	-2,858352881	13,77358143	0,006719997
France vs Japan	-2,616859829	15,51767752	0,009717604
France vs Korea	1,976751141	12,78069141	0,035754382
France vs Singapore	-1,799737219	13,44067215	0,047571131
France vs Spain	-2,259736647	22,6887189	0,017040149
France vs UK	-1,877125318	14,38516447	0,040748415
France vs USA	-3,517851915	19,19705055	0,001150111
Germany vs Indonesia	7,348235363	5,62861484	0,000366291
Germany vs Ireland	3,226293635	2,063883084	0,042062702
Germany vs Italy	-1,953584121	52,26010304	0,028069953
Germany vs Korea	7,119948841	44,92938166	3,81E-09
Germany vs Malaysia	3,096251309	56,48373606	0,001529755
Germany vs Thailand	2,224072875	8,684155958	0,028409977
Germany vs USA	-2,90932803	46,63674073	0,002781473
India vs Indonesia	5,459370052	6,093019236	0,000786751
India vs Ireland	3,352902245	3,770131672	0,021982031
India vs Korea	2,68790701	3,070557143	0,037273231
India vs Thailand	2,159888042	4,822518849	0,048450626
Indonesia vs Italy	-8,039107339	5,333721422	0,000240881
Indonesia vs Japan	-7,877003227	5,546854187	0,000265005
Indonesia vs Korea	-5,464784225	5,215341927	0,00139633
Indonesia vs Malaysia	-6,301845133	5,619662996	0,000740231
Indonesia vs Netherlands	-7,790838153	5,087633585	0,000278992
Indonesia vs Singapore	-7,471981748	5,294237369	0,000338972
Indonesia vs Spain	-7,380713425	7,448870325	7,59E-05
Indonesia vs Switzerland	-4,799113425	8,456015523	0,000678537
Indonesia vs Thailand	-4,737681422	9,748287867	0,000531191
Indonesia vs UK	-7,492113278	5,408058811	0,00033476
Indonesia vs USA	-8,333216598	6,012896303	8,11E-05

Ireland vs Italy	-3,541615304	2,034126281	0,035651757
Ireland vs Japan	-3,489320431	2,055674845	0,036612991
Ireland vs Netherlands	-3,122972471	2,007845832	0,044524957
Ireland vs Singapore	-3,244360377	2,030121986	0,041652286
Ireland vs Spain	-3,468483275	2,248195634	0,03700644
Ireland vs Switzerland	-2,697254649	3,407081346	0,036978911
Ireland vs UK	-3,270721545	2,041664556	0,041063686
Ireland vs USA	-3,793952905	2,102113341	0,031490466
Italy vs Korea	11,36957378	90,45562785	2,14E-19
Italy vs Malaysia	5,500339954	60,90924932	4,12E-07
Italy vs Netherlands	3,715874469	69,73527773	0,000203788
Italy vs Singapore	2,372602198	87,37106225	0,009933614
Italy vs Thailand	3,079215781	7,891090639	0,008917509
Italy vs UK	1,95861521	72,09726438	0,027015895
Japan vs Korea	9,364532897	49,37845411	8,50E-13
Japan vs Malaysia	4,725320641	57,99603877	7,72E-06
Japan vs Netherlands	2,019618224	32,22384233	0,025931761
Japan vs Singapore	1,758553501	54,60172677	0,042159659
Japan vs Thailand	2,912803011	8,463588378	0,009752572
Korea vs Malaysia	-3,380557087	53,40050052	0,000682257
Korea vs Singapore	-9,164637016	97,27161961	4,27E-15
Korea vs Spain	-5,294447588	14,2594037	5,67E-05
Korea vs UK	-8,544395602	67,27826295	1,26E-12
Korea vs USA	-9,298367374	34,97448154	3,63E-11
Malaysia vs Netherlands	-4,204404837	42,33959017	6,70E-05
Malaysia vs Singapore	-3,64356942	58,62091966	0,00028775
Malaysia vs Spain	-3,150310827	18,51131933	0,002767281
Malaysia vs UK	-3,630104664	60,69055625	0,000293695
Malaysia vs USA	-5,635302404	48,51253719	4,50E-07
Netherlands vs Thailand	2,292347254	7,231601702	0,027807396
Netherlands vs USA	-3,407650679	27,02780147	0,001034773
Singapore vs Thailand	2,29996478	7,784843803	0,027496975
Singapore vs USA	-3,233124372	38,5741639	0,001266818
Spain vs Thailand	2,676752509	13,07144271	0,009509083
Thailand vs UK	-2,358600441	8,090478232	0,023029368
Thailand vs USA	-3,623480487	9,722801791	0,002770808
UK vs USA	-2,935522419	42,54382791	0,002690252

APPENDIX G. VALUES FOR MACROECONOMIC INDICATORS & COUNTRY SCORES

In this appendix firstly the macroeconomic indicators and their values with respect to every country are shown in the first 2 tables. In the 3rd table the corresponding factor scores per country are shown.

Country	Total tax rate (% of commercial profits) .	GDP per Capita 2006	GDP growth	Inflation	Roads Paved	Motor Vehicles per 1000 people
Austria	53	39.300	3,70	1,40	100	553
Belgium	60	37.919	2,70	1,80	78,2	538
Denmark	32,7	50.462	3,40	1,90	100	450
France	65,8	35.457	1,40	1,70	100	598
Germany	48,9	32.491	2,90	1,60	100	549
India	72,8	830	9,30	6,10	47,7	15
Indonesia	37,3	3.448	4,30	13,10	53	47
Ireland	26,4	52.333	5,40	3,90	100	500
Italy	76,2	29.289	1,50	2,10	100	677
Japan	53,3	31.934	2,20	0,20	78,2	594
Korea	32,3	24.656	4,70	2,20	77,8	329
Malaysia	36	5.499	4,00	3,60	80,1	304
Netherlands	45,4	37.361	2,70	1,20	100	504
Portugal	45,2	19.065	1,40	2,70	86	509
Romania	49,5	5.681	7,90	6,60	30,2	172
Singapore	23,8	47.334	4,50	1,00	100	149
Spain	61,9	28.025	4,10	3,50	99	591
Sweden	54,9	43.949	4,30	1,40	31,7	517
Switzerland	28,8	54.140	3,80	1,10	100	566
Thailand	37,6	3.143	5,10	4,60	88	134
UK	35,8	40.481	2,20	2,30	100	521
UAE	14,4	45.554	9,90	9,30	100	272
USA	47,6	44750	1,90	3,20	100	818

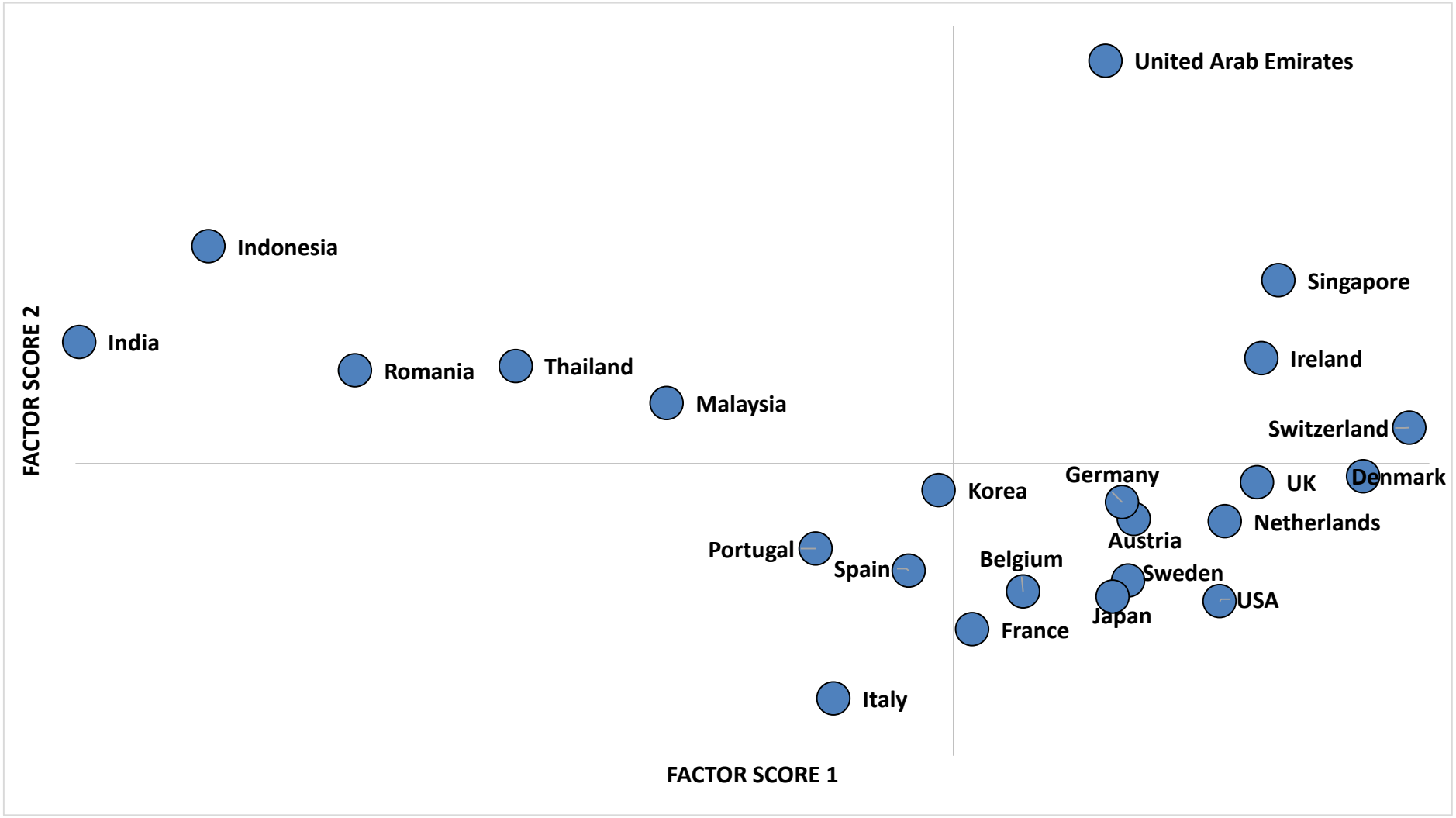
Country	Internet users (per 100 people)	GNI per Capita	Tertiary school enrollment	Numbeo cost of living index	Corruption perception index	Ease of doing business index
Austria	63,6	36140	49,00	97,88	8,60	75,80
Belgium	59,7	34480	63,00	108,04	7,30	72,50
Denmark	86,7	52250	79,00	119,95	9,50	79,80
France	46,9	36760	55,00	103,24	7,40	62,80
Germany	72,2	37210	38,00	91,64	8,00	77,80
India	2,8	2460	12,00	30,92	3,30	41,40
Indonesia	4,8	2920	17,00	46,14	2,40	47,90
Ireland	54,8	37110	58,00	112,33	7,40	83,80
Italy	38	32560	66,00	101,42	4,90	64,40
Japan	68,7	38600	58,00	115,24	7,60	76,90

Korea	78,1	18920	98,00	80,44	5,10	74,50
Malaysia	51,6	5810	31,00	54,82	5,00	71,70
Netherlands	83,7	43390	60,00	103,90	8,70	73,90
Portugal	38	22240	55,00	75,31	6,60	66,30
Romania	24,7	10860	52,00	51,89	3,10	60,00
Singapore	59	30590	20,00	105,39	9,40	90,20
Spain	50,4	29820	68,00	83,14	6,80	69,70
Sweden	87,8	36120	79,00	114,46	9,20	78,00
Switzerland	75,7	44220	46,00	151,77	9,10	72,50
Thailand	17,2	7030	44,00	51,78	3,60	66,70
UK	68,8	41190	59,00	102,24	8,60	83,20
UAE	52	64660	25,00	75,48	6,20	64,00
USA	68,9	46280	83,00	80,54	7,30	84,60

Country	Factor Scores Compnent 1	Factor Scores Component 2
Austria	0,49	-0,38
Belgium	0,19	-0,88
Denmark	1,12	-0,09
France	0,05	-1,13
Germany	0,46	-0,26
India	-2,39	0,83
Indonesia	-2,04	1,49
Ireland	0,84	0,72
Italy	-0,33	-1,61
Japan	0,43	-0,91
Korea	-0,04	-0,18
Malaysia	-0,78	0,41
Netherlands	0,74	-0,40
Portugal	-0,38	-0,58
Romania	-1,64	0,64
Singapore	0,89	1,25
Spain	-0,12	-0,73
Sweden	0,48	-0,80
Switzerland	1,25	0,25
Thailand	-1,20	0,67
UK	0,83	-0,13
United Arab Emirates	0,41	2,76
USA	0,73	-0,94

APPENDIX H. GRAPHICAL REPRESENTATION OF COUNTRY SCORES

In this appendix the countries are plotted according to their scores on factor 1 (x-axis) and factor 2 (y-axis)



APPENDIX I. COST ESTIMATION IN VARIOUS PROJECT STAGES

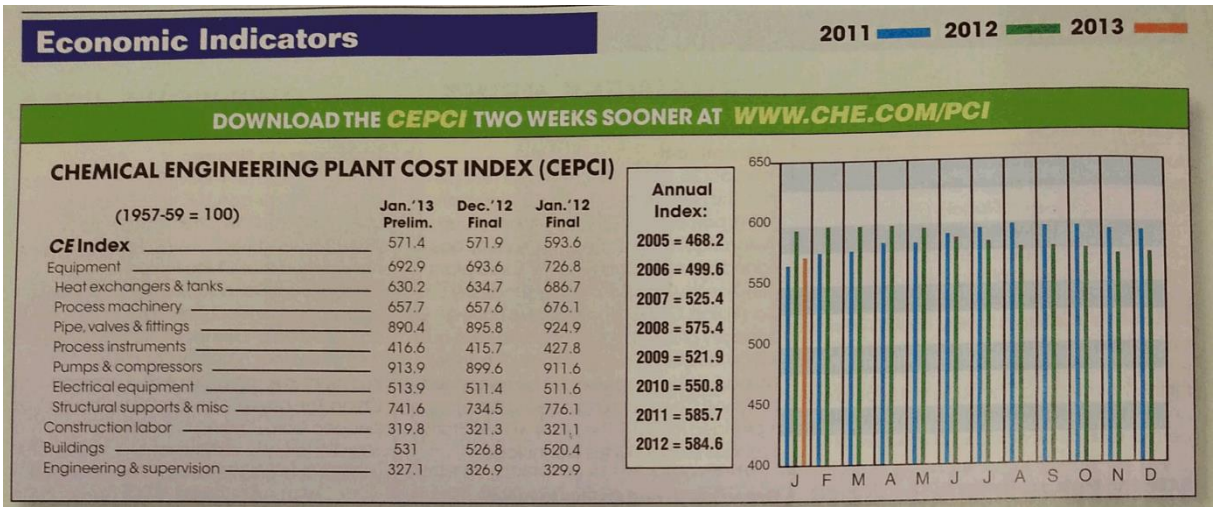
Table 23: An overview of information needed in various cost estimation stages

Source: Perry's Chemical Engineers Handbook (Couper et al., 2008)

		Information Either Required or Available				
Estimate types	Detailed (firm)					
	Definitive (project control)					
	Preliminary (budget authorization)					
	Study (factored)					
	Order of magnitude (ratio)					
Site	Location		•	•	•	•
	General description		•	•	•	•
	Site survey			•	•	•
	Geotechnical report			•	•	•
	Site plot plan and contours				•	•
	Well-developed site facilities					•
Process flow	Rough sketches		•			
	Preliminary			•		
	Engineered				•	•
Equipment	Rough sizes and construction		•	•		
	Engineered specifications				•	•
	Vessel data sheets				•	•
	General arrangement			•	•	
	Final arrangement					•
Buildings and structures	Rough sizes and construction		•			
	Foundation sketches			•		
	Architectural and construction			•	•	•
	Preliminary structural design			•	•	
	General arrangements and elevations				•	•
	Detailed drawings					•
Utilities and services	Rough quantities		•			
	Preliminary heat balance			•		
	Preliminary flow sheets			•		
	Engineered heat balance				•	•
	Engineered flow sheets				•	•
	Detailed drawings					•
Piping and insulation	Preliminary flow sheets		•	•		
	Engineered flow sheets				•	•
	Piping layouts and schedules					•
	Insulation rough specifications			•		
	Insulation applications				•	•
	Insulation details					•
Instrumen-tation	Preliminary list			•		
	Engineered list				•	•
	Detail drawings					•
Electrical	Rough motor list and sizes		•	•		
	Engineered list and sizes				•	•
	Substation number and size			•	•	•
	Preliminary specifications			•	•	
	Distribution specifications					•
	Preliminary interlocks and controls				•	
	Engineered single-line diagrams				•	•
	Detailed drawings					•
Work-hours	Engineering and drafting		•	•	•	•
	Construction supervision					•
	Craft labor				•	•
Project scope	Product, capacity, location, utilities, and services	•	•	•	•	•
	Building requirements, process, storage, and handling					

APPENDIX J. CHEMICAL ENGINEERING PLANT COST INDEX

In this appendix the Chemical Engineering Plant Cost Index (CEPCI) is shown.



Economic Indicators

2011 2012 2013

DOWNLOAD THE *CEPCI* TWO WEEKS SOONER AT WWW.CHE.COM/PCI

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957-59 = 100)	Jan.'13 Prelim.	Dec.'12 Final	Jan.'12 Final
***CE* Index**	571.4	571.9	593.6
Equipment	692.9	693.6	726.8
Heat exchangers & tanks	630.2	634.7	686.7
Process machinery	657.7	657.6	676.1
Pipe, valves & fittings	890.4	895.8	924.9
Process instruments	416.6	415.7	427.8
Pumps & compressors	913.9	899.6	911.6
Electrical equipment	513.9	511.4	511.6
Structural supports & misc	741.6	734.5	776.1
Construction labor	319.8	321.3	321.1
Buildings	531	526.8	520.4
Engineering & supervision	327.1	326.9	329.9

Annual Index:
2005 = 468.2
2006 = 499.6
2007 = 525.4
2008 = 575.4
2009 = 521.9
2010 = 550.8
2011 = 585.7
2012 = 584.6