Juha-Pekka Suomela

Selection Criteria of Engineering-to-order Manufacturing Suppliers for Project Deliveries

School of Technology and Innovation
Master's thesis in
Industrial Management

Vaasa 2020

UNIVERSITY OF VAASA
School of Technology and Innovation
Author: Juha-Pekka Suomela
Title of the Thesis: Selection Criteria of Engineering-to-order Manufacturing Suppliers for Project Deliveries
Degree: Master of Science
Programme: Industrial Management
Supervisor: Ville Tuomi
Year: 2020 **Pages:** 83

ABSTRACT:

This research studies the characteristics of the Engineer-to-Order (ETO) manufacturing and the selection criteria of the ETO manufacturing supplier. The main goal is to find relative importance of the four main criteria (quality, cost, time and flexibility) when selecting the ETO manufacturing supplier. This research studies also whether the background of the people has an effect to the criteria selection.

The ETO manufacturing is by default project-based activity, where final delivery is based on the customer requirements and specification - therefore the nature and challenges of the projects are researched on the theory part together with the ETO manufacturer supplier selection criteria. There is a lot of relevant material available for project management and sourcing on general level, but less academic material can be found on this specific area of interest. The study highlights several challenges with the project deliveries; delivery scope changes, resource management, cost issues to name a few. To manage these challenges a structured project management approach is needed, and appropriate tools must be in place.

This research is based on the nomothetical methodology with empirical approach and data is based on a survey done in the case company. The responders of the survey are known and have long working experience in the case company and are in contact with the ETO manufacturers directly or indirectly - therefore the data gathered is valuable and relevant. The response rate is relatively high (75%), indicating that the questions are relevant, and the survey was clear and understandable. The survey was done anonymously.

The Case Company is a multi-national corporation with a several business units. The actual division, which this research was completed with, is manufacturing AC drives for different industries; HVAC, water & wastewater, process industry, food & beverage and marine to name a few. AC Drives are used for electric motor speed control and energy conversion and management, and the benefits of using drives are better process control and energy savings.

Findings suggest that the four main criteria (quality, cost, time & flexibility) should not be equally weighted when selecting a supplier for ETO manufacturing; Quality and cost should have a higher importance, leading to a dilemma because these two criteria are somewhat contradictious. Background of the responders has a certain effect to the criteria selection; however, the differences are not statistically significant. Further study on this field is recommended.

KEYWORDS: Engineering-to-order manufacturing, project delivery, supplier selection criteria

VAASAN YLIOPISTO
Tekniikan ja Innovaatiojohtamisen Yksikkö
Tekijä: Juha-Pekka Suomela
Työn nimi: Selection Criteria of Engineering-to-order Manufacturing Suppliers for Project Deliveries
Tutkinto: Kauppatieteiden Maisteri (KTM)
Koulutusohjelma: Tuotantotalous
Työn valvoja: Ville Tuomi
Vuosi: 2020 **Sivumäärä:** 83

TIIVISTELMÄ:

Tämä lopputyö tutkii Engineer-to-Order (ETO) – valmistusta ja ulkoisen sopimusvalmistajan valintakriteerejä. Lopputyön tavoitteena on löytää neljän kategorian (laatu, kustannus, aika & joustavuus) keskinäinen suhde ulkoisen sopimusvalmistajan (Contract Partner) valintaa varten. Lisäksi tutkitaan, onko henkilöiden taustalla vaikutusta valintakriteereiden määrittelyyn.

ETO valmistus on käytännössä aina projektitoimintaa, jossa lopputuote perustuu asiakkaan vaatimuksiin ja määrittelyihin. Tämän takia lopputyön teoriaosuudessa perehdytään projektitoimitusten ominaisuuksiin ja haasteisiin sekä sopimusvalmistajan valintaan. Tutkimusmateriaalia on hyvin saatavilla projektitoiminnasta ja ETO valmistuksesta yleisesti, mutta ETO valmistuksen ulkoistaminen on vähemmän tutkittu alue. Teoriaosuudessa huomataan, että pääasialliset haasteet projektitoimituksessa ovat projektin muutoksien hallinta, resurssien ohjaus ja projektin kustannuksien seuranta ja hallinnointi. Lisäksi projektitoimitusten menestyksellinen hoitaminen vaatii järjestelmällistä lähestymistapaa ja oikeita työkaluja.

Tämä lopputyö perustuu nomoteettiseen tutkimusmetodiin, jossa käytetty data perustuu kohdeyhtiössä tehtyyn sisäiseen kyselyyn. Kyselyn kohderyhmänä on kohdeyhtiön omat työntekijät, jotka ovat tekemisissä ulkoisten ETO valmistajien kanssa säännöllisesti. Näin varmistetaan kerätyn materiaalin luotettavuus ja merkityksellisyys. Kysely tehtiin nimettömänä. Kyselyn vastausprosentti on erittäin hyvä (75 %) joten kyselyn kysymykset ovat merkityksellisiä, ymmärrettäviä ja hyvin muotoiltuja.

Kohdeyhtiö on monikansallinen yritys, jolla on toimintoja eri teollisuuden sektoreilla. Tämä lopputyö tehtiin yrityksen Drives-segmentille, joka valmistaa taajusmuuttajia eri teollisuusaloille kuten kiinteistöt, merenkulku, energiateollisuus, vedenkäsittely ja prosessiteollisuus yleisesti. Taajuusmuuttajia käytetään oikosulkumoottorien nopeusohjaukseen, mutta myös etenevissä määrin energian hallintaan eri sovelluskohteissa. Taajuusmuuttajien käyttö parantaa prosessin hallintaa ja mahdollistaa energian säästön ja hallinnan.

Lopputyön löydökset osoittavat, että toimittajan valinnan kriteerien (laatu, kustannus, aika & joustavuus) painotus ei ole tasainen; laatu ja kustannus nousevat selkeästi esiin tärkeimpinä valintakriteereinä. Tämä voi olla haaste, koska laatu ja kustannus ovat osittain vastakkaisia kriteerejä. Lisäksi vastaajien taustat vaikuttivat osittain kyselyjen tuloksiin, ei kuitenkaan tilastollisesti merkittävästi.

AVAINSANAT: Engineering-to-order manufacturing, project delivery, supplier selection criteria

Foreword

I started my studies in the Vaasa University year 1997, while my studies for Bachelors of Engineer on Electrical Engineering were still on-going. The idea of combining the technical studies together with the financial & industrial management knowledge was interesting. When I received my Bachelor´s Degree I started to work on the local company and continued my studies on weekends and evenings. However, 2004 our dear daughter Sonya was born, and year after the whole family moved to Germany - that time my studies were put on hold. We all came back to Vaasa on 2008 with our new family member David, and we started to renovate our newly bought farmhouse while my dear wife & I needed to work on the side of all this – at this point the continuation of my studies did not even cross to my mind.

Years passed, children grew, and situation stabilized. Even the house started to be in decent condition. At some point one of my work colleague took a study leave and I started to think of my Master´s studies again… I hate to leave things half-done. After discussions with the University it was clear that I had the possibility to continue my studies, and my employer allowed me to take one-year leave from the work.

So here we are – my studies took 23 years to complete. Personally, it has been a great journey, although it took a while. I have learned a lot. I want to say my sincerely thanks to the Vaasa University for allowing this opportunity, and I am grateful to my supervisor Ville Tuomi. Many thanks also to all my studying friends, especially to Mika Fred for his support. I am deeply thankful for the Danfoss Drives and my superior Jouko Liljeström for allowing me to take a time off. Thanks goes also to Niko Saarinen for his inspiration. The family and friends have been extremely supportive, thank you all very much. Special thanks also to Merikaarron Lämäri for Friday evening's social event - I needed that. Last, but not least; Thank you Johanna. I love you.

J-P Suomela

Contents

Figures

Tables

Abbreviations

CTO = Configured to Order
EMEA = Europe, Middle East and Africa
ETO = Engineering to Order
HVAC = Heating, Ventilation & Air Conditioning
KPI = Key Performance Indicator
MTO = Make to Order
OEM = Original Equipment Manufacturer

1 Introduction

In recent years, the competition has intensified in the form of the service or product availability: Customers expect to have what they want in the exact time slot they need it. This has led to fact that supply chain's flexibility is becoming more crucial. In a matter of fact one can say that instead of companies supply chain networks compete against each other (Oliveira & Gimeno, 2014).

One way to be competitive is to offer customer exactly what they want, and manufacture the final product or solution based on the customer requirements. The scale can differ from individual to industrial level – from personal wearing to machinery or systems. Common for all of those is that the specification of the final delivery is based on the customer demand and is unique, at least on some extent. Companies which can differentiate and customize their offering according to customer needs have a substantial competitive advantage if they can keep the cost base in reasonable level.

This final thesis describes the nature of the ETO manufacturing on industrial projects and reviews the criteria when selecting the ETO manufacturing supplier. It studies two ETO manufacturing suppliers in the case company and tries to identify the different aspects of the supplier selection and relative importance of them.

1.1 Motivation

The idea for my final thesis subject grew up during my studies. During my professional career I have been working with different project deliveries where major part of the engineered solution was designed, manufactured and procured by sub-contractor or manufacturing supplier. There are many internal and external stakeholders with complex, engineered delivery projects; customer, manufacturing & engineering supplier, supply chain responsible, sales, service and product development to name few. All these stakeholders have typically a different viewpoint of the Key Performance Indicators (KPI's), or at least they are weighting them differently. For some the cost is the main issue to be

considered, others the delivery on time. Usually quality is an issue where there are no compromises, but quality level can be valued differently by different stakeholders. Flexibility is also seen as an important issue with project deliveries.

The purpose of this final thesis is to study the criteria when selecting a manufacturing supplier for an engineered-to-order (ETO) product. Target is rank the importance of cost, quality, flexibility and time dimensions for optimum supplier selection.

1.2 Research Questions

One can say that all the issues listed on the previous chapter are important, but are some more important than others? They seem to have a contingency between each other, and by putting heavy weight on single aspect, i.e. delivery time, it might increase the costs and put quality on danger. Would it be possible to measure and rank the different aspects when selecting the engineering-to-order manufacturing supplier? This leads to the main research question:

What are the main aspects to be considered when selecting an engineering-to-order manufacturing supplier?

This question is relatively common; therefore, it needs to be divided to following subcategories:

A: Experiences on past and present at the case company
A1: How successful the past deliveries by manufacturing suppliers have been?
A2: What were the main constraints and challenges?

B: Important dimensions for case company for the future
B1: How different dimensions should be weighted when selecting the manufacturing supplier?
B2: How to evaluate existing / potential manufacturing suppliers?

These questions are the main guidance for this research. The goal is to find out what kind of experiences the case company has with ETO manufacturing suppliers (A1 & A2), and how to evaluate manufacturing suppliers (B1 & B2). The research is done by completing a survey for the case company personnel, where both the past experiences and the future requirements for the ETO manufacturing suppliers is asked. Further on the responders are asked to rate the different dimensions when selecting the manufacturing suppliers.

2 Literature Review

There are different production planning strategies available to fulfill the market demand: make-to-order (MTO), assemble-to-order (ATO), configure-to-order (CTO), finish-to-order (FTO), engineering-to-order (ETO) and queuing (Oliveira & Gimeno, 2014). This literature review concentrates on engineering-to-order manufacturing strategy and was made by emphasizing high-quality books and peer reviewed scholarly journals. The literature review is divided to three different chapters; First section introduces the ETO manufacturing, it´s characteristics and typical nature of the operations. Second section describes the challenges with the ETO manufacturing and methods to overcome these. Last section concentrates on supplier selection criteria in the ETO manufacturing viewpoint.

2.1 Engineering-to-Order (ETO) Manufacturing Project

Engineering-to-order manufacturing refers to manufacturing process where customer order is manufactured according to customer specifications. In theory it is a pure design-to-order process where customer expectations are met by designing and manufacturing a unique product, like designer pair of shoes for a certain customer. However in order to speed up the manufacturing process companies tend to use make-to-order strategy when possible; in this strategy product is based on standard design but it will be customized according to customer specification, like in case with expensive homes (Krajewski;Malhotra;& Ritzman, 2016).

A case study highlights that ETO manufacturing can be divided to four different main types based on the engineering complexity and average annual units sold: Complex ETO, Basic ETO, Repeatable ETO and Non-competitive ETO (Wilner;Powell;Gerschberger;& Schonsleben, 2016). Complex ETO produces unique, customer specific, low volume and high-engineered products, like shipbuilding industry. Basic ETO concentrates on low volume and low engineering products with only partial customer specific engineering, like asphalt mixing plants. Repeatable ETO manufactures products with high volumes and

low engineering complexity, like high rise elevators. This is close to MTO manufacturing but still requires certain amount of customer specific engineering. Non-competitive ETO would provide products with high volumes and high engineering. This is a very unlikely situation and writers of the case study could not find any concentrate example of this type of ETO (Wilner;Powell;Gerschberger;& Schonsleben, 2016).

As ETO manufacturing is based on customer specification it needs at least some level of project approach with project management tools, methods and measurement. Project can be defined as of a “temporary endeavor undertaken to create a unique product, service or result” (A guide to the project management body of knowledge (PMBOK guide), 2017). Depending on the industry, customers, and product or solution complexity there are various ways to handle the delivery project, however certain issues are generic and described below.

2.1.1 Project planning

First delivery project needs to be planned and it is defined according to PMBOK guide as “the document that describes how the project will be executed, monitored, and controlled”. It includes plans and documentation how to manage the project and typical components are project integration, scope, schedule, cost, quality, resources, communication, risk, procurement and stakeholder management which are described more detailly in following sections (A guide to the project management body of knowledge (PMBOK guide), 2017).

2.1.2 Project integration

According to PMBOK Guide the project integration includes “the processes and activities to identify, define, combine, unify, and coordinate the various processes and project management activities within the Project Management Process Groups”. In practice project integration management means making choices about resource allocation, compet-

ing demands, seeking alternatives and alternating the processes according to project demands (A guide to the project management body of knowledge (PMBOK guide), 2017). It also includes planning, controlling and managing the project by use of different tools and techniques.

2.1.3 Project scope management

Scope management is a very crucial part of the ETO manufacturing project to ensure successful and effective project execution. It includes scope planning, definition, verification and change management (Khan, 2006). By managing the scope changes it is possible to evaluate the impact of those changes to project key deliverables, and therefore quantify the effect on project cost and time constraints (Nahod, 2012). If scope is not properly defined and controlled, it can lead to uncontrolled scope creep which increases project costs and schedule (Alp, 2012).

2.1.4 Project scheduling

Project scheduling works as a roadmap for the different stages of the project. A classical project scheduling method is called Waterfall model. In this method project is divided to different phases with pre-defined tasks which needs to be completed before project can proceed to next phase (Ajam, 2017). It gives a structured approach with clear milestones and targets, however it is criticized being too rigid and including too much up-front planning for certain projects, like for software development. The answer for this need has been the raise of the Agile method, which is especially developed for software development, but has been used also in the other project areas. Instead of fixed stage gates it is based on continuous design with flexible scope, continuous customer involvement and freezing specification as late as possible (Serrano & Pinto, 2015). Recent years there has been also hybrid systems where Waterfall and Agile are combined to so-called hybrid model where best sides of both methods are utilized, resulting in structured planning and flexibility (Conforto & Amaral, 2016).

2.1.5 Project cost management

Project cost (budget) planning and managing have a key role to ensure project reaches the financial targets. Cost estimation of the project should be done as reliable as possible already during the project quotation phase. The challenges might be the lack of necessary technical data and tight enquiry schedule, and in many cases cost estimation is relying on expert judgement and past experiences (Hoosmand;Köhler;& Korff-Krumm, 2016). Costs are in close relation with the scope and the schedule, and any change or challenge with those can change the project costs to positive or negative direction. In case the customer requirement changes, the project cost & impact analysis needs to be carried out (Hoosmand;Köhler;& Korff-Krumm, 2016). There are various ways to follow up the costs, but the fundamental idea is to compare the actual costs against the anticipated costs. One of the most common used method is the Earned Value Management (EVM), which compares the earned value to planned value based on scheduling baseline (Muriana & Vizzini, 2017). In order to have an effective and functional cost follow-up the level of detail and update cycle should be clearly defined and communicated (Bagherpour, 2010).

2.1.6 Project quality management

Quality is a cornerstone for a successful ETO manufacturing project. John S. Oakland defines quality as “meeting the customer requirements”. He also states that “companies compete on its reputation, and that quality is the key to achieving sustained competitive advantage” (Oakland, 2014). Challenges with the quality targets will cause challenges to cost and schedule targets and can jeopardize future business with the customer if quality problems are not managed and communicated properly. Project quality management include quality planning, assurance and control activities (Nastase, 2013).

2.1.7 Project resource management

The success of any organization is highly dependent on the appropriate use of its resources; people, facilities, machinery, inventory etc. In order to project to achieve its

targets it needs to have right resources available at the right time (Tjahjana;Dwyer;& Habib, 2009). Resource needs are changing in different project phases (definition and organization, planning, execution, close out) so constant monitoring of project progress is vital to ensure project has required amount of resources (Krajewski;Malhotra;& Ritzman, 2016). Often these resources are requested by several different projects, so an efficient company level resource management and allocation system is needed.

2.1.8 Project communication

In the project environment effective communication is a must for project success; Project team members need to know their tasks, project manager must know the status of these tasks, and customer expectation needs to be clearly defined and communicated. In order to make sure that customer expectations and instructions are reaching all the necessary project team members and stakeholders open, regular and accurate communication channels need to be created and maintained, and is a responsibility of the project manager (Samakova;Babcanova;Hrablikchovanova;Mesarorova;& Sujanova, 2017).

2.1.9 Project risk management

Risk management tries to anticipate and mitigate possible project risks by quantifying the risks, predicting their impact and creating necessary contingency plans (Krajewski;Malhotra;& Ritzman, 2016). Risks within the ETO manufacturing can be i.e. technical, schedule, costs, scope and resource related. It is important to understand that risks vary depending on the project size, complexity and importance (A guide to the project management body of knowledge (PMBOK guide), 2017).

2.1.10 Project procurement

Procurement in the project includes all the processes and actions necessary to purchase products, services or results outside the project team to achieve the project goals. The actual people managing the contracts, purchase orders etc. may be members of the project team, or part of the organization department (A guide to the project management

body of knowledge (PMBOK guide), 2017). If project procurement is managed poorly it can lead to material shortages, missed deadlines and un-controlled cumulation of the costs (Rane;Narvel;& Bhandarkar, 2019). In practice procurement is often dependable of the design engineering; actual purchases cannot be executed before the engineering documentation of the deliverable have necessary components and materials clearly defined and identified.

2.1.11 Project stakeholder management

Project has a various amount of the stakeholders – people or groups - that might affect or be affected by the project. In order to anticipate the expectations and the engagement of these stakeholders, effective stakeholder management planning and implementation is needed (Eskerod;Huemann;& Savage, Project Stakeholder Management - Past and Present, 2016). Organization's internal stakeholders might have a different view of the project deliverables and emphasize classical project dimensions (cost, time & scope) differently. Unsatisfied stakeholders can cause a lot of distortion and even failure of the project. A study about available project management standards recommends to "actively interact with only a limited number of project stakeholders, i.e. the most important project stakeholders in terms of their harm and help potentials" (Eskerod & Huemann, Sustainable development and project stakeholder management: what standards say, 2013).

2.2 Challenges with ETO Manufacturing Project

Fundamental purpose of ETO manufacturing is to create customer specific, purpose-built product or solution. Eventually all ETO manufacturing is project manufacturing, and lack of the project discipline and methods in the organization can prevent a successful outcome of the ETO project (Yang, 2013). Especially with complex deliveries the engineering part takes largest part of the lead time, and therefore this part of the process needs to be carefully controlled with clear and agreed target dates (Grabenstetter & Usher, 2015).

Customer requirements are an essential part of the engineering and manufacturing process, and final product is defined by the customers and the engineers (Yang, 2013).

2.2.1 Project integration and scope change management

A study done by Mario Henrique Mello, Jan Ola Strandhagen and Erlend Alfnes suggested that “both the integration of engineering and production and the production capability are the most critical factors influencing coordination in an ETO supply chain”. Their study, done for the shipbuilding industry, prove that with the complex ETO supply chains having diverse companies performing various activities (i.e. design, engineering, procurement, manufacturing, assembling and commissioning) coordination is crucial for successful project delivery (Mello;Strandhagen;& Alfnes, 2015). Scope change management, which is typically an important part of the project manager’s duties, is crucial for managing project costs and schedule. With complex projects, like in shipbuilding, it is almost certain that there will be scope changes and they can be disruptive on project deliverables if not effectively managed (Mello;Strandhagen;& Alfnes, 2015). Good project management techniques, processes, competences and tools will ease the coordination of the complex ETO project. Typical approach is to agree on a date by which the design needs to be approved by the customer - changes to the specification after that date might have an effect to delivery time and costs.

2.2.2 New technologies

If ETO manufacturing project has a new, unproven technology it can cause delays and challenges when new solution needs to be tested. Complex projects with multiple stakeholders using new technology calls a lot of interaction and coordination between parties and can be very time consuming, especially if proposed design fails to meet the requirements (Mello;Strandhagen;& Alfnes, 2015). Another challenge with new technology or solution is the cost; companies often have difficulties to evaluate what will be the project costs, thus leading to project profitability challenges when developing something new

to satisfy customer requirements (Johnsen & Hvam, 2018). While introducing new technology with ETO project can be risky, it is sometimes needed for companies to win the competition. Introducing new technologies should bring competitive advantage for a company and for the customers, i.e. lower costs, more product/solution features and improved functionality. However, level of risk needs to be evaluated (financial, technical, delivery, functionality) and decision needs to be based on achieved benefits against potential risks and the costs (Muriana & Vizzini, Project risk management: A determistic quantitave technique for assessment and mitigation, 2017).

2.2.3 Production and engineering capability

Production and engineering capability play an important role with the ETO manufacturing. Organizations with experienced engineering team and adequate resources are able to provide the necessary documentation for the production and make adjustments, if necessary (Mello;Strandhagen;& Alfnes, 2015). Lack of the competent engineering resources can cause challenges with the coordination and inefficient usage of the production capacity - In some occasions manufacturing will be started with preliminary design in order to get the production started, and if there is a need to change the design later it will cause challenges and need for design documentation updates (Mello;Strandhagen;& Alfnes, 2015). Engineering process generally dictates the production schedule, as the engineering documentation needs to be at adequate level before ETO manufacturing can be started. Engineering can be seen as a most important aspect dictating the lead time of the ETO project, and challenges are typically complex projects, limited information or in some cases even a defects in a released order (Grabenstetter & Usher, 2015). In order to speed up the engineering and manufacturing processes companies try to base their designs on past deliveries and rely on existing engineering databases, thus minimizing the actual time and effort needed for ETO project. This will also ease the cost evaluation on project bid phase and help with the risk management when certain part of the design is already done and manufactured before.

2.2.4 Procurement

Procurement for ETO manufacturing is highly dependable of the customer requirements and engineering. If the ETO manufacturer has produced a similar design already earlier and customer specification is clear and confirmed, component procurement is less of a challenge and mostly concentrating on the availability of the components from the suppliers. In case of the new, complex design procurement can be challenging and requiring a lot of resources and effort, especially if new suppliers need to be searched and selected (Krajewski;Malhotra;& Ritzman, 2016). New customer or unclear customer specification can also bring complexity to the procurement process. To manage complex ETO project procurement it is important to have an agile organization, methods and tools which allow efficient management of the project procurement. Appropriate use of the digitalization and automatization can also bring substantial effectiveness for the procurement process. Naturally top management support and commitment is crucial; Project procurement personnel should have an adequate empowerment to make necessary decisions instead of applying for approval of all cost related activities from top management (Rane;Narvel;& Bhandarkar, 2019).

2.3 Supplier Selection Criteria

Organizations everywhere seek today competitive advantages to their supply chains by outsourcing, offshoring and even by forming strategic alliances. With complex ETO manufacturing processes the flow of materials, products, transactions and especially information is a crucial step for the successful operation. By selecting the right supplier(s) when building a supply chain is a key issue for sustainable competitive advantage, and by forming mutually beneficial partnership with the suppliers it is possible to achieve even higher performance and better results (Cheng & Carillo, 2012).

When selecting a manufacturing supplier(s) it is essential to identify and select the right processes and scale for the outsourcing. Company might want to use a vendor for a subprocess or outsource complete operation, and options include from sole supplier model,

where single supplier provides the entire service, to panel model where several preferred suppliers compete for each project or contract (Oshri;Kotlarsky;& Willcocks, 2009). With ETO manufacturing typical outsourcing areas are engineering and manufacturing, partly or completely. While outsourcing can bring substantial cost benefits it needs to be planned and managed carefully in order to achieve the anticipated benefits (Oshri;Kotlarsky;& Willcocks, 2009). Management and employee capabilities also play role in the selection of the ETO manufacturing supplier; Is the management customer focused? Are they willing to invest to sustain and grow the business? Do they have a vision about company future? Are the employees committed to quality and continuous improvement? Do they have the necessary skills and expertise? How is the morale and flexibility of the people? The issues above are often challenging to find out in the beginning of the co-operation, however the management and employee capability play an important role of the day-to-day business and competitiveness of the supplier, as well as the financial stability of the supplier (Handfield;Monczka;Larry;& Patterson, 2009).

What would be the right criteria for selecting an ETO manufacturing supplier? The traditional way to define and measure project delivery success is so called “Iron Triangle” or “Project Management Triangle” including Time, Cost and Quality. It is widely accepted for its simplicity to measure “whether the project is delivered by the due date, within budget, and to some agreed level of quality, performance or scope” (Pollack;Helm;& Adler, 2018). These categories are related to each other, and challenges with one criterion can put pressure on the other criteria. Naturally, there are other criteria used for the project success measurement, and there has been a discussion whether the third criterion, quality, is a right choice or should it be changed to i.e. scope, performance or requirements. However, “Iron Triangle” is consistently supported concept in the project management literature, research and practice (Handfield;Monczka;Larry;& Patterson, 2009).

Other relevant literature and studies introduces a competitive priorities model with four different categories: Cost, quality, time and flexibility (Krajewski;Malhotra;& Ritzman,

2016) (Ward;McCreery;Ritzman;& Sharma, 1998). These categories can be divided to different sub-categories and have different weighting in different industries. A recent literature review about project procurement management highlighted seven most important categories when selecting suppliers in project environments: Quality, cost/price, staff features, financial, company management, experience and time (de Araujo;Alencar;& de Miranda Mota, 2017). Cost, quality and time are directly highlighted, and rest of the categories can be directly or indirectly categorized as flexibility; staff features, company management, experience and even financial. As a point of interest article also reveals that different project types tend to have a different weighting for the different criteria; i.e. quality is first with the aviation project whereas cost is main driver with the highway projects. Moreover, the same article raises the need to "conduct exploratory studies on the perception of different stakeholders in contractual partnerships in the supplier selection phase" (de Araujo;Alencar;& de Miranda Mota, 2017). It seems that these four categories define supplier selection criteria more thoroughly than the traditional "Iron Triangle". To have a deeper knowledge of the four main categories, they will be evaluated more detailly in the following sections from the ETO manufacturing perspective.

2.3.1 Cost

Cost criteria is typically clearly defined and can be measured with quantitative methods, however with complicated ETO manufacturing cost comparison between different suppliers can be demanding and time consuming. For example, material and workhour costs are easily comparable between different candidates, however with i.e. engineering the experience and competence of the supplier engineering resources has a huge impact on the time needed to accomplish the given task, resulting in a differing efficiency with different suppliers (Handfield;Monczka;Larry;& Patterson, 2009). When considering costs with ETO manufacturing suppliers, possible added value actions should be also considered; is the supplier candidate capable of doing the engineering at the basic level, or can they even come up with new designs and ideas for the customer company in order to

bring competitive advantage or save costs? (Handfield;Monczka;Larry;& Patterson, 2009).

Supplier location has also an impact to the cost; although the engineering & manufacturing documentation can be transferred electronically and virtual meetings are de-facto procedure, demanding ETO projects often need parties to meet face-to-face, especially in case of unexpected challenges. If ETO manufacturing supplier is locating far away from the client company, time and money will be spent for the logistics of the people & goods. This need to be taken into account with the cost comparison, especially if supplier is located in another country, where taxes, tariffs and government regulations can increase the cost significantly (Oshri;Kotlarsky;& Willcocks, 2009).

2.3.2 Quality

When one thinks of the quality with manufacturing supplier for ETO projects, quite often people end up of thinking the quality of the delivered product or solution. However, quality needs to be understood and defined with wider perspective. Ron Basu divided quality in projects in his article “Managing quality in projects: An empirical study” to three different dimensions; Design, process and organization quality (Basu, 2014). Basu also highlighted the importance for all the stakeholders to have common definition of the quality, having the formal quality management systems and procedures in place, and train the suppliers for the quality systems and procedures. A formal quality audit procedure with all three quality dimensions should also be implemented and executed (Basu, 2014). Challenge here might be that some quality measurements are quantitative and easy to follow up (i.e. defect rate of the delivery), whereas others are more qualitative and based on personal judgement (quality of operations). Certifications and quality models like ISO, TQM etc. provides a framework which can be used as a base for the definition of the quality.

2.3.3 Time

One important aspect of any project delivery is time – Capability of manufacturing supplier to deliver the right amount, on right time (and with right quality). This aspect is not purely depending on the manufacturing supplier - project scope and communication have a significant effect for delivery performance. The early identification of the key project parameters and early project scope freezing will increase the overall efficiency of the project delivery (Eldin, 2005). However, if the manufacturing supplier has built adequate capacity and flexibility to their processes and operations, they will be more likely be able to fulfill the deliver demands even in uncertain conditions (Handfield;Monczka;Larry;& Patterson, 2009).

2.3.4 Flexibility

Manufacturing capacity is the maximum rate of output of a process and or a system and needs to have long-term planning. ETO manufacturing is a subject to variable demand, and whereas large capacity can work as a cushion for demand variation, it can cause inefficient usage of the resources thus decreasing operational performance (Krajewski;Malhotra;& Ritzman, 2016). Therefore ETO manufacturing supplier need to have also flexibility in their processes and operations, and this means a responsiveness to schedule, mix, design or service changes (Handfield;Monczka;Larry;& Patterson, 2009). Manufacturing flexibility can be achieved in many ways; capability of the workstations to produce multiple products, possibility to relocate operators between different workstations, flexible work hour system for employees etc. (Jain;Jain;Chan;& Singh, 2013).

Complex ETO project can require a design changes even after the order is received, leading to changes in the specification and need for re-engineering and multiple design versions (Vaagen;Kaut;& Wallace, 2017). Engineering capability of ETO manufacturing supplier is especially important if engineering of the product or solution will be done partly

or completely by the supplier. Good engineering capability improves the operational efficiency and increases the flexibility of the operations with project deliveries. The engineering capability includes the amount and competence of the engineering staff, engineering tools used, and standards supplier is able follow on their design. If engineering is done as a collaborative action between supplier and purchaser, the design tool platforms needs to be compatible and be able to utilize same data source. This kind of approach increases also the importance of the communication and design review and version handling procedures (Iakymenko;Romsdal;Semini;& Strandhagen, 2018).

Sourcing & procurement capability of the ETO manufacturing supplier have an important role if the supplier needs to source the components for the delivery. General challenge with the ETO procurement is that ETO projects have unique customer specific designs, and their inventory levels are typically low. Necessary components can be ordered only after the engineering and customer have defined and agreed about the final product (Yang, 2013). With standard, long lead time components supplier can set up a safety stock in order to guarantee the shortest possible delivery time (Krajewski;Malhotra;& Ritzman, 2016). Instead of sourcing, supplier can also have manufacturing capability which improves the performance of the supply chain, i.e. mechanical manufacturing for small batch production like busbars, fittings etc.

2.3.5 Environmental issues

Environmental issues are largely dictated by the governmental regulations and rules, and there are standards defining environmental requirements like ISO18001, OHSAS etc. However, improvements beyond regulatory can bring sustainable improvements to company operations by i.e. energy efficient manufacturing, decreased use of the raw material and improved production processes (Cagno;Micheli;& Trucco, 2012). One should not also forget the impact of the reputation; customers are more environmental consciousness than ever, and companies need to show that environmental issues are considered when they are building up their supply chain processes. Therefore, ETO manufacturing

supplier should have environmental issues in-built to their processes and operations, and they should be able to show the results and benefits they have been able to achieve.

3 Case Company Danfoss Drives

Case company is a Danfoss Drives, which is a part of the Danfoss Group. Danfoss is privately owned global company with headquarter in Denmark and have more than 28 000 employees globally. It has four main business segments - Power solutions, Cooling, Heating and Drives which provide products and solutions to several different markets. 2019 Danfoss had a revenue of 6,3 billion Euro with 771 million EUR EBITA.

3.1 Products

Danfoss Drives manufactures AC drives for electric motor speed control and energy conversion and management. The benefit of using drives in the speed control of electric motors is better process control and energy savings. Recent years the electrification and hybridization of the different industries has also created an access to new customers and markets. The customer base is wide and consists different industrial verticals, like marine & offshore, HVAC (Heating, ventilation & Air-conditioning), water & wastewater, energy, food & beverage and process industry generally. Company´s product portfolio is large, ranging from the small micro-drives with power of 0.37 kW until high power liquid-cooled drives with several MW of electric power. The figure 1 & 2 shows a snapshot of the Danfoss Drives product portfolio. The variations of the applications where AC drives are used varies a lot; fans, pumps, conveyors, lifts, cranes, winches, propulsion and so on.

Figure 1: Danfoss Drives VLT product range

Figure 2: Danfoss Drives Vacon product range

3.2 Manufacturing strategy

Danfoss Drives is a product company which relies on manufacturing-to-order and lean operations. Major part of the manufactured items are productized, high volume products with restricted amount of options and fixed type codes. Supply chain is designed according to these principles with low inventories, fast delivery times and high utilization of capacity. However, Danfoss Drives is also delivering “tailored products” where final product is designed according to customer specification. Large part of these are so-called OEM (Original Equipment Manufacturer) product where AC Drives are designed together with the customer, and after customer approvals these products are standardized, productionized and manufactured with high volumes. Typical example of this business segment is elevators; elevator manufacturers require purpose-built ac drive installed on their elevators, and due to fact that volumes are high this approach is widely adopted in the industry by both elevator and AC drives manufacturers.

3.3 Enclosed drives

Another example of the “tailored products” are “Enclosed drives” which are engineered-to-order according to customer specification. These drives are enclosed in the cabinet compartment and include AC drive module with additional external components like filters, breakers, switches and control components. Danfoss Drives have a standard range of the “Enclosed Drives” available, but certain industries and customers require product based on their specification, at least to some extent. These requirements vary, but typically they are related to control circuitry and mechanical design; customer can require a special control logic which standard solution does not offer, or special color & labels in the cabinet, or special physical size due to installation area restrictions. A figure 3 & 4 shows a typical example of the Danfoss Drives Enclosed Drives which are engineered-to-order according to customer specification.

Figure 3: Typical Danfoss Drives ETO enclosed drive (air cooled)

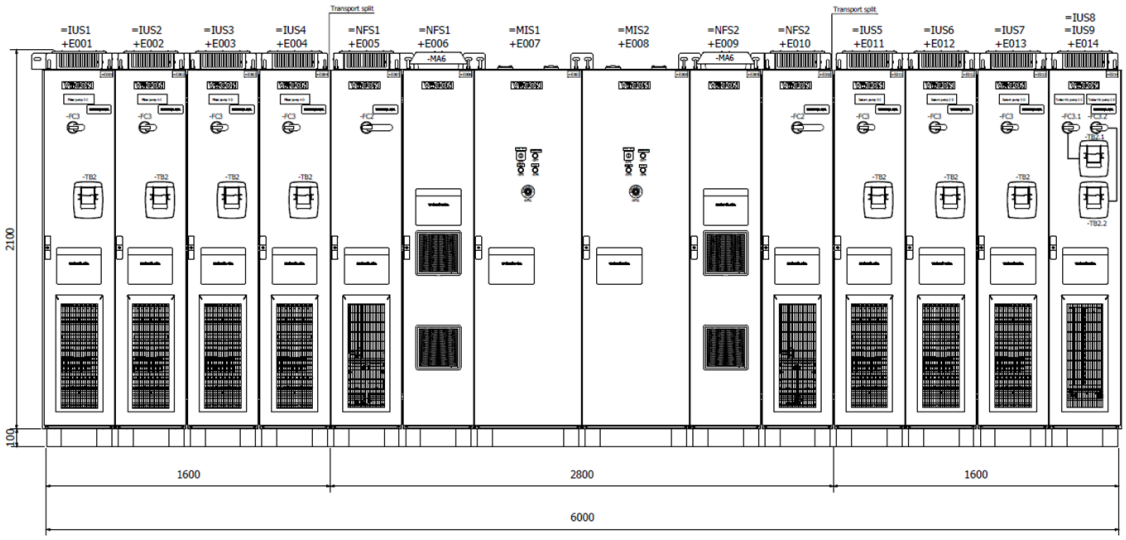
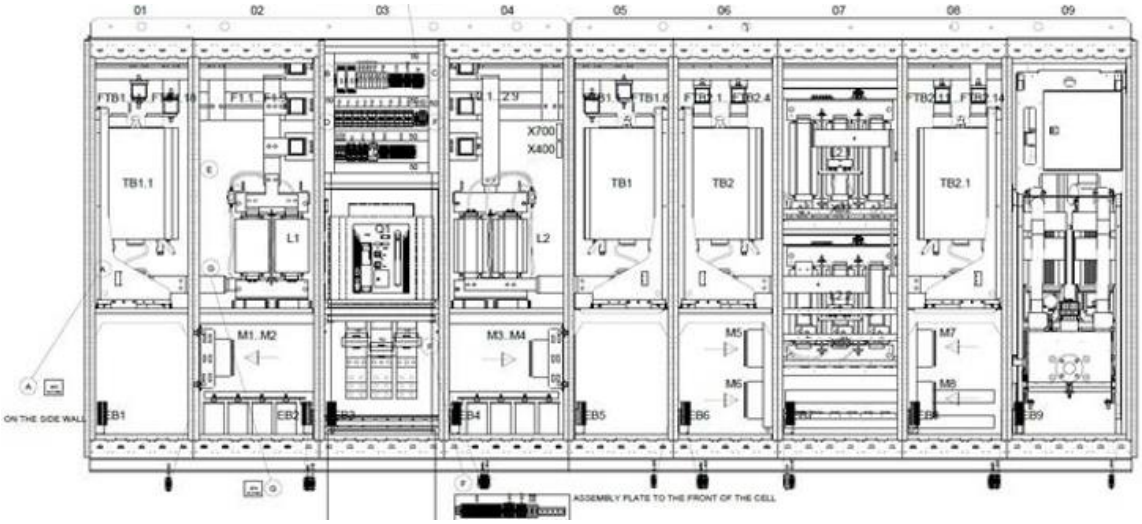


Figure 4: Typical Danfoss Drives ETO enclosed drive (liquid cooled)



3.4 ETO manufacturing

As Danfoss Drives is a product company it´s volume manufacturing facilities are dedicated for the manufacturing of the drive modules and CTO (Configured-to-order) Enclosed drives. In order to fulfill the customer requirement for ETO Enclosed drives Danfoss Drives has a selection of external suppliers for design & manufacturing these

products. They are referred as Contract Suppliers thereafter. In EMEA region the utilization of these Contract Suppliers is based on the required solution; certain suppliers are specialized on certain product range and it can be based on the specification, target industry or customer. The selection of the Contract Suppliers is based on the supplier selection criteria and managed by the sourcing organization.

4 Research Methodology

4.1 Theory

On the theoretical part of this study the supplier selection criteria were divided to four different main categories; cost, quality, flexibility and time. While those four main categories are all important, question remains if they are equally important, or should certain category be emphasized more when case company is selecting an ETO manufacturing supplier? In the literature review it was found that depending on the industry main categories are ranked differently, and that relates to the nature and complexity of the ETO manufacturing projects. Further on the ETO manufacturing project stakeholders tend to have a different viewpoint about the importance of the project deliverables (scope, cost & time), and therefore they have a different viewpoint of the supplier selection criteria (quality, cost, time & flexibility).

4.2 Hypothesis

Literature review revealed two hypothesis that will be tested against the collected material:

H1: The four categories of the ETO manufacturing supplier selection criteria (quality, cost, time and flexibility) should not be weighted equally.

H2: The view of the weighting criteria differs depending on the background of the responders (organization and work role).

These hypotheses will be tested against the gathered data.

4.3 Research Method

There are basically two main research methodology approach which could have been used on this research; Nomothetical and normative. Nomothetical is concentrating on the question “how things are currently”, whereas normative is asking “how things should be in the future”. Further, the research methods can be divided to either theoretical or empirical, where theoretical is based on the purely conceptual approach where theory is not tested against the real data, whereas empirical is using the actual collected data. The table 1 below shows the two different research methods with two practical approaches (Helo;Tuomi;Kantola;& Sivula, 2019).

Table 1: Research method quadrant

	Theoretical	**Empirical**
Nomothetical	Conceptual - Ontology development	Descriptive - Survey - Exploratory case study
Normative	Decision support - Decision support - Simulation	Design study - Six-sigma, lean - Process improvement - IS design

When the topic of this research was decided, it was not clear whether the case company would have a necessary amount of data to be used as a research material. After discussions with several stakeholders in the case company it turned out that there was data which could be used for the research, but case company was more interested to find out how the different stakeholders in the company see the quality of the services provided

by the Contract Suppliers. Therefore, it was decided to create a survey where the status of the active operations would be judged from the people working on different functions in the company. There was also a discussion of including the selected end customers on the survey, but that was postponed for possible later stage.

As the collected data on this research is based on the data collected from the survey, this research is based on the nomothetical methodology with empirical approach.

4.4 Data Collection

Case company have a Contract Supplier assessment in place, and data has been collected for several years. To find out the relation between each category the theoretical background (quality, cost, time & flexibility) was compared to existing supplier assessment methodology used in the case company. The comparison table 2 can be found below.

Table 2: Comparison table of theoretical background to case company metrics

Theorethical definition (competitive priorities of manufacturing strategy)		Danfoss metrics	Main subject	Questions
Quality	Low defect rate	FAT test (defects / section)	Low defect rate	Deliveries by Contract Supplier has very low defect rate
	Product performance	Customer satisfaction survey	Meets customer specification	Deliveries by Contract Supplier meets customer specification
	Reliability	Testing: procedures and test setup	Adequate testing by contract supplier	Testing (FAT) done by the Contract Supplier is adequate and professional
	Environmental aspect	ISO 14001, RoHS, Reach		
	Certification	Certificates (ISO 9001, Switchgear, etc)		
Cost	Low cost	Right cost (labor & components)	Right cost level	Contract Supplier provides a right cost level in order to compete in the market
	Value added	Participation in shared cost down projects		
	Quality costs	Project quality costs (warranty) - 8D	Low quality costs	Deliveries by Contract supplier have very low quality costs
	Activity based measurement	Sourcing: competence and scale		
	Continuous improvement	Year-to-year cost development	Year-to-year cost development	Contract supplier is able and willing to provide improved year-to-year cost development
Time	Fast delivery	Lead time	Fast lead time	Contract Supplier provides competitive delivery time
	On agreed time	Planned vs actual shedule OTD	OTD (time, amount)	Contract supplier delivers always on time and right amount
	Right amount	Planned vs actual shedule OTD		
	Right quality	SPPAP per project delivery		
	Dependable promises	Response time	Fast & relevant response	Response (project support, quotes) from the Contract Supplier is fast and relevant
Flexibility	Design adjustment	Engineering capability (competence, tools)	Engineering capability	Contract Supplier has necessary engineering capability (competence, resources, tools) for design adjustments
	Volume change	Manufacturing capability	Manufacturing capability	Contract Supplier has necessary manufacturing capability to fulfill market demand (volume, mix)
	Mix changes	Manufacturing capability	Procurement capability	Contract Supplier has necessary procurement capability for securing the delivery and reacting to changes
	Broad product line	Right porfolio (LV/MV)		

Based on the comparison above a questionnaire with most relevant topics for the case company was created. This survey was sent to 71 persons working in the case company. The selection of responders was based on their role and co-operation with the different Contract Suppliers in EMEA (Europe, Middle East & Africa) sales region. This region was

selected due to substantial amount of the business within the ETO deliveries. The functions & role description of the responders is included in the table 3 below.

Table 3: Function and role in the company

Function	Role	Amount
After Market Service	Technical support and service of Enclosed Drives	11
Center of Excellence	Technical enquiry support & project management of Enclosed Drives	11
Marketing	Marketing of the Enclosed Drives	2
Product Management & Development	Product management & development of the Enclosed Drives	7
Sales	Sales of Enclosed drives	30
Supply Chain	Source, procure & manufacture of Enclosed Drives	10

The tool used for the material collection was “SurveyXact” software application, which case company is using for the surveys. The selection of the tool had a benefit of getting support for the survey creation and the responders being familiar with the tool. The survey was sent as a link with email, and it was completed in the period of one week. The survey was sent as anonymous in order to get the honest and trustworthy response.

4.5 Validity and reliability

4.5.1 Validity

This study does not include any analyzation of the Case Company´s records or collected data, instead it is solely relying on the survey responses. However, the responders were carefully selected and are working in the functions where they can see the effects of the operations and deliverables of the Contract Partners:

Sales is working closely with the customer and will get feedback if the quotation or delivery is

- not fulfilling the customer specification
- has a quality problem
- cost level is not at the right level
- not at the right time at the right place.

Center of Excellence is responsible of the offered and delivered solutions by the Contract Suppliers and works closely with them. They are responsible of the engineering, although the actual work can be done by the Contract Partner. They can observe the quality and flexibility of their operations and deliverables, and if the tasks are executed on time.

After Market Service is responsible of the commissioning and service of the products delivered by the Contract Partner. In case of any problems they will be noted, and they are expected to take an action.

Supply chain is responsible of the selection and assessment of the Contract Suppliers and they are in close contact with them regularly. Their KPI´s (Key Performance Indicators) are delivery time, quality & cost development. They are constantly developing their supplier base to find suppliers with the right quality and cost level.

The responders are known, and all are working for the Case Company. Selection of the responders was done together with the people responsible of the process and operations. The survey was done anonymously, so individual answers cannot be traced. This was done in order to have the real and honest feedback from the target group. When considering all the facts above, the data gathered from the survey is trustworthy and valid.

4.5.2 Reliability

To measure the reliability of the collected data Cronbach's Alpha was used. Cronbach's Alpha is widely used method to "measure of the internal consistency of a test or scale, and it is expressed as a number between 0 and 1". (Tavakol & Dennick, 2011). There are different views of the acceptable level of the alpha, and they range from the 0,70 to 0,95. If alpha gives a low value, it can be due to the low amount of questions, inadequate inter-relation between items or too heterogenous construct. On the other hand, too high alpha might be an indication of having same questions from different angle. There are also discussions of the improper use of the Cronbach's Alpha, leading to the situations in which "either a test or scale is wrongly discarded, or the test is criticized for not generating trustworthy results". Nevertheless, Cronbach's Alpha is a popular statistical tool for testing the reliability of the collected data (Tavakol & Dennick, 2011).

The survey questions were grouped on two groups: Past performance & future expectations of the Contract Suppliers. Therefore, it was sensible to use the same grouping for the reliability analyzation of the questions. Both groups included three questions for each of the main categories (quality, cost, time & flexibility) – so totally there were 12 questions per group.

The Cronbach´s Alpha reliability analyzation of the collected data can be seen on the table 4 below:

Table 4: Cronbach´s Alpha of different question groups

	Respon-ders	Min	Max	Mean	Stdev	Cronbach´s Alpha
Past performance	54	5,00	6,83	4,98	1,31	0,84
Future Expectati-ons	52	3,25	6,92	5,16	0,93	0,78

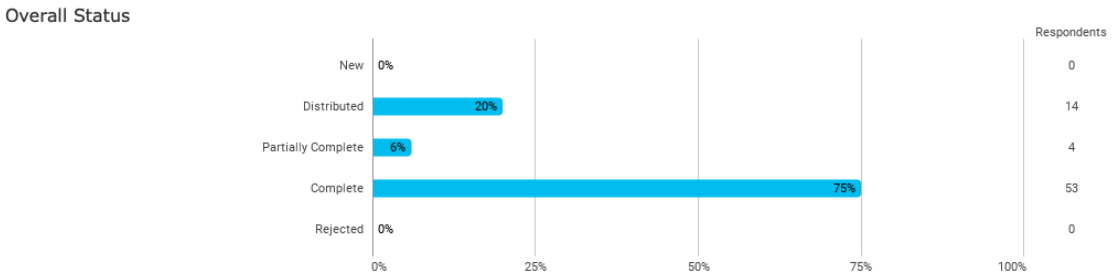
Cronbach´s Alpha reveals that the results of both categories are reliable (over 0,7), however it seems that the “past performance” data is more consistent. The amount of the questions was same on both groups, but the standard deviation is significantly lower on the “future expectations”, indicating that the responders have a similar view of the requirements for the future requirements.

5 Results & Analyzation

5.1 Background of the Responders

The total response rate for the survey can be found on the table 5 below:

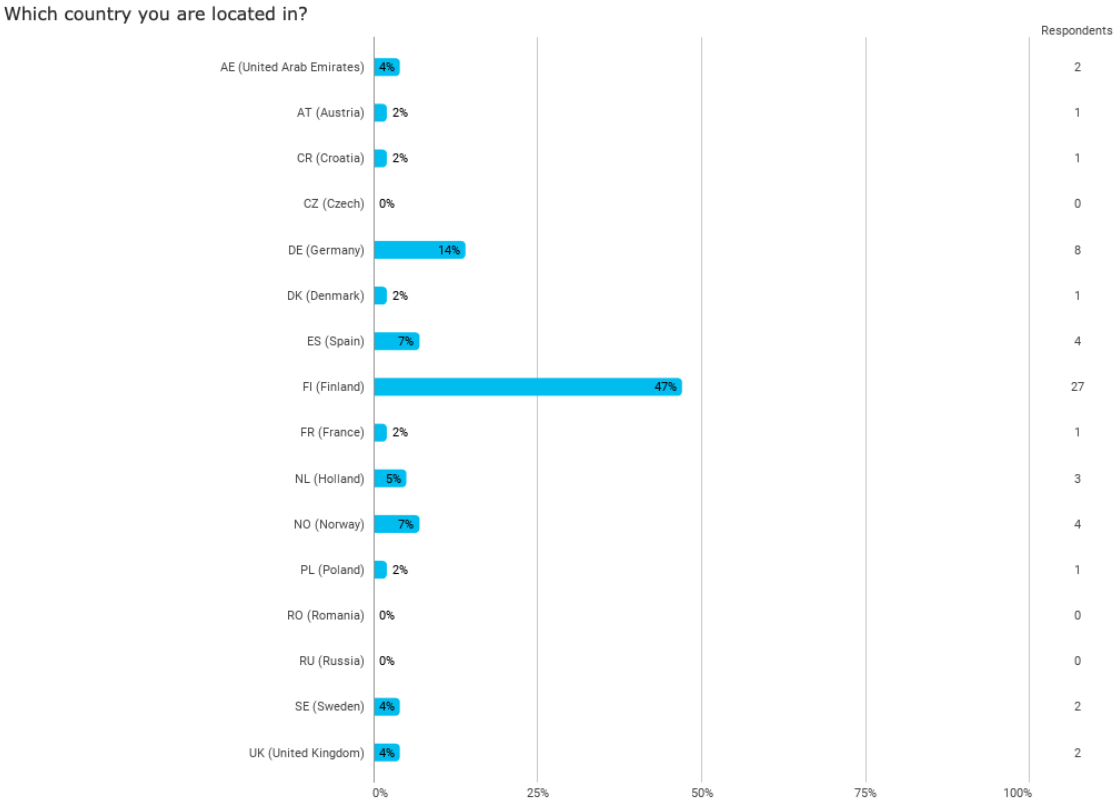
Table 5: Response rate of the survey



75% (53) of the responders completed the survey, and 6% (4) partially. This is a very good result.

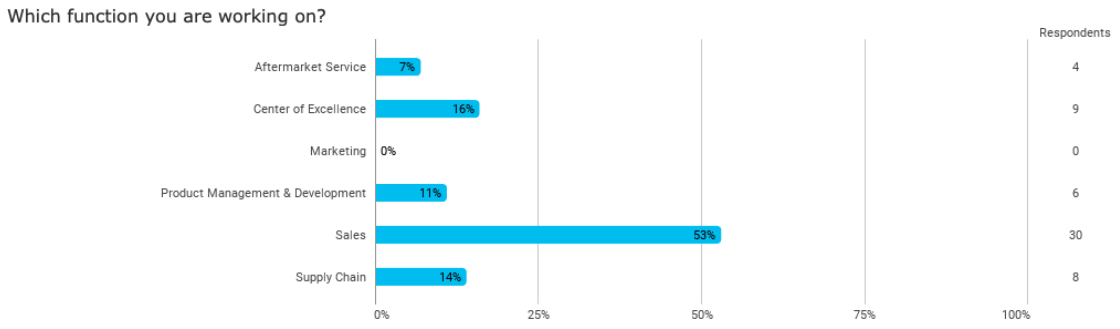
The background of the responders can be found from the tables 6 - 9 below:

Table 6: Country responders are locating



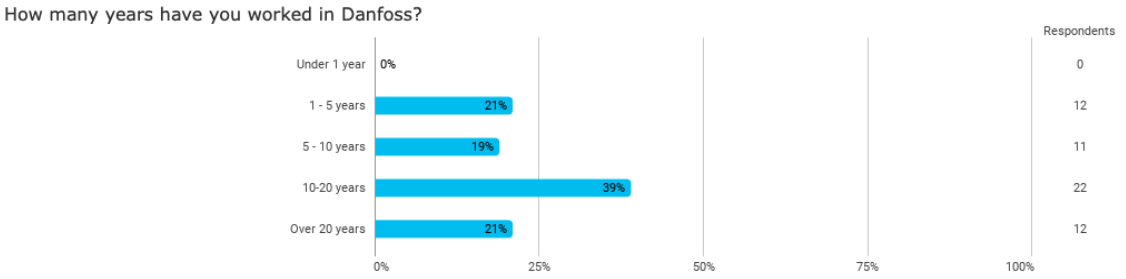
The proportion of the responders from Finland is high (47%) due to fact that major part of the functions & personnel working with Contract Suppliers are based in Finland.

Table 7: Function the responders are working



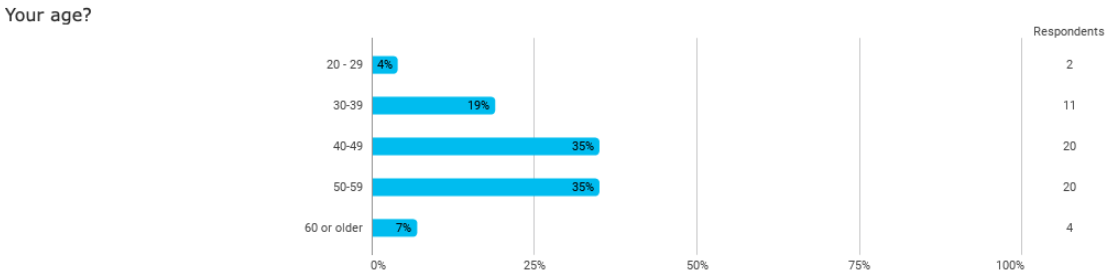
53% of the responders are working on sales. Other functions which replied were After Market Service, Center of Excellence, Product Management & Development and Supply Chain. There was no reply from Marketing.

Table 8: Years responders have worked in Danfoss



60% of the responders have worked more than 10 years in Danfoss so responders have long perspective of the business & market requirements.

Table 9: Age of the responders



77% of the responders are older than 40 years, which implies that responders have long work experience and thus have a good base for the evaluation of the suppliers.

The appendix 1 includes the survey questions in detail. Questions were grouped to four different categories (quality, cost, time & flexibility) based on the findings in the theoretical part. Each category includes three different questions, and both past performance and future requirements were asked to find whether there are gaps between current

situation and future requirements. Totally there are 24 questions on this part. The assessment uses Likert scale from 1 (strongly disagree) to 7 (strongly agree) for past performance, and 1 (much lower importance) to 7 (much higher importance) for future requirements.

Further on the responders were asked to rank the four categories (quality, cost, time & flexibility) from most important to least important. The idea behind this question is to find out whether the answers distributes equally or are there indications that certain categories are more important to responders and should have a higher weight in the supplier selection and assessment.

5.2 Overview

The tables 10 & 11 below shows descriptive statistics of the past performance and future requirements questions grouped under four main categories (quality, cost, time & flexibility). Minimum, maximum, mean and standard deviation are averages of the answers of each category (three questions per category).

Table 10: Descriptive statistics of the past performance in the scale 1 to 7 (7 = best)

Past performance	Respondents	Min	Max	Mean	Stdev
Quality	54	2,67	7	5,79	1,02
Cost	54	1,33	6,33	4,27	1,35
Time	54	1,67	7	4,72	1,56
Flexibility	54	1,67	7	5,14	1,32

The lowest score for past performance is given to “cost” category, and it has also second highest standard deviation, indicating that there is high variance in the answers. Highest score is given to “quality” and it has lowest standard deviation.

Table 11: Descriptive statistics of future requirements in the scale 1 to 7 (7 = highest)

Future require-ments	Respondents	Min	Max	Mean	Stdev
Quality	53	3,67	7	5,09	0,95
Cost	52	3,67	7	5,35	0,87
Time	52	3,33	7	5,18	1,03
Flexibility	52	4	6,67	5,00	0,86

The highest importance for the future requirements is given to “cost” category, and it has also second lowest standard deviation. The lowest importance is given to “flexibility”, and it has lowest standard deviation.

Interesting finding is that the differences between lowest and highest means is much higher in the past performance (1,52) compared to the future requirements (0,35). The standard deviation is also less in future requirements, indicating that responders have rated different categories quite similarly.

The following table 12 shows the comparison between the past performance and future requirements means.

Table 12: Comparison of means of past performance & future requirements

Category	**Mean / Past**	**Mean / Future**	**Difference**
Quality	5,79	5,09	0,70
Cost	4,27	5,35	-1,08
Time	4,72	5,18	-0,46
Flexibility	5,14	5,00	0,14

The largest difference is in the cost category. It also has the lowest score in the past performance and highest for the future requirements. This category needs to have a further look and analyzation, especially in the past performance rating.

5.3 Past Performance

Following table 13 shows the descriptive statistics of the past performance cost related questions.

Table 13: Descriptive statistics of the past performance cost related questions in the scale 1 to 7 (7 = best)

Question	Min	Max	Mean	Stdev
1 Contract Supplier provides a right cost level to be competitive in the market	1	6	4,15	1,58
2 Deliveries by the Contract Supplier has very low-quality costs	2	7	4,91	1,15
3 Contract Supplier is able and willing to provide improved year-to-year cost development	1	6	3,76	1,32

The 1st and 3rd question have low score with high standard deviation. 2nd question seems to indicate that responders are satisfied with the quality, as can be seen in the quality category.

Based on the theory part of this research the background of the responders should have an effect to the scores. Following table 14 & 15 includes the analysis of the questions 1 & 3 from the previous table based on the function the responders are working.

Table 14: Comparison of means and variance for past performance cost related question 1 based on responder's work function

Function	Responders	Mean	Variance
Sales	29	3,93	3,14
Aftermarket Service	4	3,75	4,25
Supply Chain	8	4,75	1,36
Product Management & Development	4	4,25	2,92
Center of Excellence	9	4,44	1,03

On question 1: “Contract Supplier provides a right cost level to be competitive in the market” Sales and After Market Services functions are providing lower scores comparing to rest of the organization. This question relates to market pricing, and obviously sales should have the best view of the market price level. It should be noted that their opinion should be weighted more on this matter.

Table 15: Comparison of means and variance for past performance cost related question 3 based on responder’s work function

Function	**Responders**	**Mean**	**Variance**
Sales	29	3,69	2,15
Aftermarket Service	4	4,50	0,33
Supply Chain	8	3,00	1,14
Product Management & Development	4	4,00	2,67
Center of Excellence	9	4,22	0,69

On question 3: “Contract supplier is able and willing to provide improved year-to-year cost development” Supply Chain is providing by far lowest average score comparing to rest of the functions. Supply Chain is working constantly with the suppliers and they should have a best view of the year-to-year cost development, therefore their opinion on this matter should have more importance.

As there are two different suppliers on the survey next step is to analyze past performance categories based on the supplier selection. Following tables 16 & 17 include descriptive statistics for the four different categories of supplier 1 & 2.

Table 16: Past performance of supplier 1 in the scale 1 to 7 (7 = best)

Past performance	Respondents	Min	Max	Mean	Stdev
Quality	15	3,00	7,00	5,47	1,20
Cost	15	2,33	6,00	4,47	1,07
Time	15	2,67	6,67	5,16	1,39
Flexibility	15	2,67	7,00	5,11	1,22
			Average	5,05	1,22

Table 17: Past performance of supplier 2 in the scale 1 to 7 (7 = best)

Past performance	Respondents	Min	Max	Mean	Stdev
Quality	39	3,33	7,00	5,91	0,92
Cost	39	1,33	6,33	4,20	1,43
Time	39	1,67	7,00	4,55	1,59
Flexibility	39	2,00	7,00	5,15	1,34
			Average	4,95	1,32

Supplier 2 got 39 evaluations compared to 15 evaluations for supplier 1. This is probably due to fact that supplier 2 has co-operated longer with the Case Company than supplier 1. In both evaluations' quality category received highest score – and similarly cost category lowest. Average of the means was almost the same. Table 18 below shows a comparison of the means of both suppliers for different categories.

Table 18: **Comparison of the mean values of the suppliers 1 & 2 on past performance**

Past performance	Mean / Supplier 1	Mean / Supplier 2	Difference
Quality	5,47	5,91	-0,45
Cost	4,47	4,20	0,27
Time	5,16	4,55	0,61
Flexibility	5,11	5,15	-0,03

It is notable that both suppliers are rated very similarly with the flexibility category. Largest difference between the suppliers is with the time category, where supplier 2 got 0,61 lower score than the supplier 1. In order to analyze this category further, the detailed questions for the cost category were compared, and results can be seen on table 19 below.

Table 19: Comparison of the means for suppliers 1 & 2 on past performance time category

Question	Mean / Supplier 1	Mean / Supplier 2	Difference
1 Contract Supplier provides competitive delivery time	5,13	4,82	0,31
2 Contract Supplier delivers always on time and right amount	5,27	4,79	0,47
3 Response (project support, quotes) from the Contract Supplier is fast and relevant	5,07	4,03	1,04

Supplier 2 has lower grades with all the "time" category questions compared to supplier 1. Largest difference (1,04) with the means is with the question 3: "Response (project support, quotes) from the Contract Supplier is fast and relevant". This is significant difference compared to other results and this topic should be discussed further with the Case Company and the supplier 2.

5.4 Ranking of Categories

Final part of the survey was to rank the four categories (quality, cost, time & flexibility) from first to last. For this purpose, simple, visual selection table was created, as can be seen below at table 20.

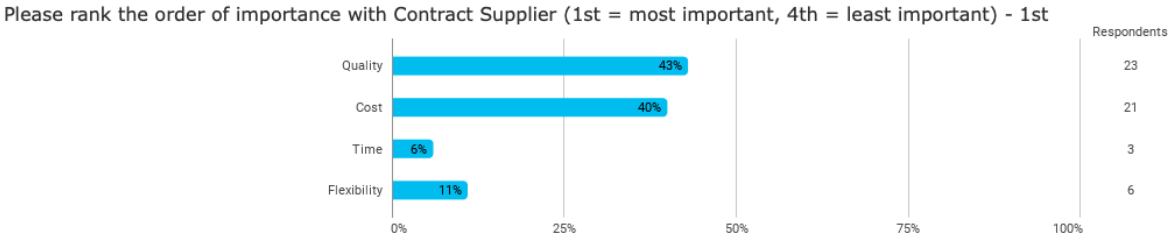
Table 20: Survey question for ranking of the different categories

Please rank the order of importance with Contract Supplier (1st = most important, 4th = least important)

	Quality	**Cost**	**Time**	**Flexibility**
1st	(2) ❑	(3) ❑	(4) ❑	(5) ❑
2nd	(2) ❑	(3) ❑	(4) ❑	(5) ❑
3rd	(2) ❑	(3) ❑	(4) ❑	(5) ❑
4th	(2) ❑	(3) ❑	(4) ❑	(5) ❑

Results reveal that distribution of the categories for the first position is not even (figure 5).

Figure 5: Results of the ranking of the categories for first position



Two categories, quality and cost, got 43% and 40% of the votes. This indicates that these two categories are rated by far highest by the responders. However, because result was tight, there is a need to have a closer look of the results and see if the background of the responders influenced the "voting" or is it a common view by the participants.

Following table 21 shows the frequency distribution of the responders divided to two different groups: Sales & Others.

Table 21: Frequency distribution of sales & other functions on ranking question

Category	Sales / Frequency	Sales / Percentage	Others / Frequency	Others / Percentage
Quality	9	33,3 %	13	54,2 %
Cost	13	48,1 %	7	29,2 %
Time	2	7,4 %	1	4,2 %
Flexibility	3	11,1 %	3	12,5 %
	27		24	

The division for "sales" & "others" is done in order to have a clear view whether sales function have a different opinion than rest of the responders and to have equal number of responders on both groups.

The first category with “Sales” is cost, with a 48,1% share, whereas “Others” rated quality as first with 54,2% share. With “Sales” quality comes as second with 33,3% share, and “Others” rated cost as second with 29,2% share. It seems there is a difference with first and second selection between these groups, however differences are not that remarkable. In sales function sales margins are always on focus, and cost of the solution or product is an important factor for possible success with the customer. Although some of the other functions are also interacting with the customers, they are not directly sales responsible, and it seems that they are more focused on the quality of the deliveries and services ETO supplier is providing.

The following tables 21 – 25 shows the frequency distribution of the group “Others”.

Table 22: Frequency distribution of After Market Services on ranking question

Category	Frequency	Percentage
Quality	2	50 %
Cost	2	50 %
	4	

Table 23: Frequency distribution of Supply Chain on ranking question

Category	Frequency	Percentage
Quality	5	62,5 %
Cost	1	12,5 %
Time	1	12,5 %
Flexibility	1	12,5 %
	8	

Table 24: Frequency distribution of Product Development & Management on ranking question

Category	Frequency	Percentage
Quality	3	75 %
Cost	1	25 %
	4	

Table 25: Frequency distribution of Center of Excellence on ranking question

Category	Frequency	Percentage
Quality	3	37,5 %
Cost	3	37,5 %
Flexibility	2	25,0 %
	8	

Quality seems to be at first position in all the groups, although in "After Market Services" it divided the first position with the cost. In "Supply Chain" quality got 62,5% of the "votes" so it seems that quality is very high on their agenda. Interesting finding is also the fact that flexibility got 25% share for the first position in "Center of excellence" function. This can be due to fact that this group is working closely with the Contract Suppliers during solution quotation and delivery phase, and flexibility of the Contract Supplier is an important factor for them in order to successfully accomplish their tasks.

5.5 Testing of Hypotheses

There are two hypotheses to be tested against the collected data:

H1: The four categories of the ETO manufacturing supplier selection criteria (quality, cost, time and flexibility) should not be weighted equally.

H2: The view of the weighting criteria differs depending on the background of the responders (organization and work role).

5.5.1 Hypothesis H1

With hypothesis H1 it can be clearly seen that different categories (quality, cost, time & flexibility) are not rated equally by the responders. Quality and cost received major part of the "votes" (43% & 40%) when responders were asked to rank the four categories in order from one to four (figure 5). So, the answer to this part is yes, the four categories should not have an equal weight.

5.5.2 Hypothesis H2

With H2 the results are more mixed. Yes, responders from different functions seem to weight the categories differently, however the differences were not remarkable. One challenge with the collected data is that “sales” function is over-presented with the responders, and therefore the data is compared as “sales vs. others”. Results reveal that both groups place “quality” and “cost” on top two, only on different order as can be seen on table 21.

However, if we expand the hypothesis H2 on the form “the view of the supplier performance rating depends on the background of the responders (organization and work role)”, we can find evidence that supplier rating depends on the background of the responders.

Descriptive statistic reveals that the past performance “time” category has largest standard deviation, indicating that results have more variation (table 10). When the “time” category is analyzed more detailly by using descriptive statistics, it gives following results (table 26):

Table 26: Descriptive statistics of the past performance “time” category questions

Question	Min	Max	Mean	Std. Dev
Contract Supplier provides competitive delivery time	2	7	4,91	1,52
Contract Supplier delivers always on time and right amount	2	7	4,93	1,33
Response (project support, quotes) from the Contract Supplier is fast and relevant	1	7	4,31	1,83

Question “response (project support, quote) from the Contract Supplier is fast and relevant” have highest standard deviation, indicating that it has largest variance with the

results. When the answers are grouped between sales & others the ANOVA analysis gives following results (table 27):

Table 27: ANOVA of the "past performance" time related question divided by sales & others (sales = 1 & others = 2)

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
1	29	108	3,724	3,921	109,793	0,321	3,079	4,369
2	25	125	5	1,917	46	0,346	4,305	5,695

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*F crit*	*RMSSE*	*Omega Sq*
Between Groups	21,855	1	21,855	7,295	0,009	4,027	0,521	0,104
Within Groups	155,793	52	2,996					
Total	177,648	53	3,352					

The results reveal that there is a significant difference between results given by sales and the other functions with the question "response (project support, quote) from the Contract Supplier is fast and relevant"; The p-value equals to 0,009 against the alpha of 0,05.

This leads to conclusion that evaluation of the suppliers can depend on the background of the responders, in this case the function they are working on.

However, if we take the average of the past performance results (12 questions) and divide it by the two responder groups (sales & others) we get a following results (table 28):

Table 28:ANOVA of the past performance results grouped by sales & others (sales = 1 & others = 2)

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
1	29	125,643	4,333	1,044	29,242	0,161	4,010	4,655
2	25	114,778	4,591	0,402	9,646	0,173	4,244	4,938

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*F crit*	*RMSSE*	*Omega Sq*
Between Groups	0,898	1	0,898	1,201	0,278	4,027	0,211	0,004
Within Groups	38,887	52	0,748					
Total	39,785	53	0,751					

There is no significant difference between the results, the p-value equals to 0,278 with an alpha of 0,05. This means that the total result of the past performance is not depending on the background of the responders when the function is the decisive factor. This is a good result for the case company – the feedback they get from the Contract Suppliers is relevant and not depending on the function they are working.

In order to get the final confirmation for the independence for the background and result we will compare the location (place of work) and results. The Finnish are dominant in the survey against the rest of the nationalities (47%), so the results of the past performance are grouped to Finnish vs rest of the nationalities. This comparison provides the following result (table 29):

Table 29: ANOVA of the past performance grouped by Finns & others (Finns = 1 & others = 2)

DESCRIPTION					Alpha	0,05		
Group	*Count*	*Sum*	*Mean*	*Variance*	*SS*	*Std Err*	*Lower*	*Upper*
1	25	108,136	4,325	0,661	15,854	0,1734	3,978	4,673
2	29	132,429	4,567	0,829	23,225	0,161	4,243	4,890

ANOVA

Sources	*SS*	*df*	*MS*	*F*	*P value*	*F crit*	*RMSSE*	*Omega Sq*
Between Groups	0,780	1	0,780	1,038	0,313	4,027	0,197	0,0007
Within Groups	39,079	52	0,752					
Total	39,859	53	0,7521					

The results reveal that the Contract Supplier grading is not depending on the country the responders are locating – the p-value is 0.31 with the alpha of 0,05, meaning that there is no statistically significant difference between the results.

All together it can be noted that the background of the responders has a relevance to the results of both weighting of the selection criteria of the Contract Suppliers, and evaluation of their performance, at least on some extent. However, when you look of the results of this research it clearly indicates that with the reasonable amount of the responders who are constantly working with the Contract Suppliers the result is stable – there are differences, but they are not statistically significant.

Therefore, the hypothesis H2 cannot be proved true on this research. With certain questions we can find statistically significant differences, but when we look the complete picture the differences are not that remarkable. For the Case Company this is a good result – they can rely on the internal survey done for the Contract Partners without fear of the effects of the background of the responders, if there are enough responses on the survey.

6 Conclusions & Discussion

In this chapter findings on this study will be summarized and conclusions will be drawn. Target is also to provide both theoretical and practical contributions and consider possibilities for further studies on this area.

6.1 Research Questions

The main research question was formulated as below:

What are the main aspects to be considered when selecting an engineering-to-order manufacturing supplier?

On the theory part it was found that the main aspects can be divided to four different categories: Quality, cost, time & flexibility. It was also found out that there is a lot of subcategories & details under these main categories, and all of those are important - but are some more important than others? In order to combine the theory and the practice following more detailed questions were formulated to be used in the study with the case company:

A: Experiences on past and present at the case company
A1: How successful the past deliveries by manufacturing suppliers have been?
A2: What were the main constraints and challenges?

B: Important dimensions for the case company for future
B1: How different dimensions should be weighted when selecting the manufacturing supplier?
B2: How to evaluate existing / potential manufacturing suppliers?

To get answers for the research questions a survey was created. It was based on the earlier literature review and is matched with the supplier assessment used in the case company. Both past performance and future requirements were considered.

Following chapters summarizes the learnings gathered during this research together with some practical contributions.

6.2 Past Performance of the Suppliers

6.2.1 Quality

As can be seen from the table 16 the quality of the two suppliers received highest score on the different categories. As we learned on the theory part quality needs to be understood and defined with wider perspective and is divided to design, process and organization quality. The responders are working on different functions of the case company and therefore it can be trusted that the feedback covers all the areas of the quality. The "future requirement" rating for the quality proves also that there is no need for a dramatic change in the quality of these Contract Suppliers. However, in order to keep and continuously improve the quality level of the Contract Suppliers formal quality management systems and procedures needs to be in place and they must be followed with discipline.

6.2.2 Cost

Cost category received lowest scores from the responders for the past performance. It has also highest difference to future requirements on the survey. Further analyzation of the answers (table 14 – 15) reveals that sales personnel gave low scores on the market cost level, whereas supply chain personnel gave negative feedback on year-to-year cost development. Based on this feedback it is recommended to make a further study on the actual cost base of these Contract Suppliers and compare it to the market price level on the market. This should be a cross-functional exercise. However, on theory part we learned that costs with complex ETO projects are not so simple to compare. Materials

and installation labor hours are straight forward & measurable costs, but in ETO projects engineering have a crucial part in the design and manufacturing of the solution. If engineering is provided by the Contract Supplier, the competence level of their engineering staff defines how effectively they can accomplish the tasks given to them. High competence leads to short execution time together with low errors and vice versa. This should be also taken into consideration when evaluating the cost of the Contract Supplier.

6.2.3 Time

Another category which got low grades in the past performance was “time”. This category was analyzed further with the comparison of the supplier 1 and 2 (table 19) and results revealed that supplier 2 got lower grades with all the time related questions. Especially low performance was given to question “Response (project support, quotes) from the Contract Supplier is fast and relevant”. Supplier 2 has been a supplier for the Case Company considerably longer time than supplier 1, and supplier 2 and Case Company should know each other very well. As response time was left “open” the responders most probably are referring to their earlier experience with the Supplier 2 so maybe something has changed? Are there changes with the supplier personnel? What is their workload? Do they have enough resources and necessary tools for their operations? It must be also noted that the reason for the experienced slow response can be at least partly at the Case Company side. Is the Case Company overloading supplier with the tasks? Are the processes and ways of working defined and efficient on their end? Are the tasks and requests given to Supplier clear with all the necessary data in order to Supplier to accomplish their tasks?

The reason for the low grade should be analyzed together with the necessary stakeholders. It would be also wise to start the measure the performance of the operations, if not already in place. By mapping the value stream, defining the process and measuring the performance it is possible to find possible bottlenecks and problems in the system and improve it by using i.e. DMAIC toolkit (Oakland, 2014). Naturally, it is recommended to use same or at least similar processes & measurement with both suppliers.

6.2.4 Flexibility

Flexibility was another category which got higher grades in “past performance” compared to “future requirements”. Further, when comparing the performance of both suppliers their score was almost equal. There might be differences on the single questions, as in any other category, but generally it seems that responders are satisfied with the flexibility of these two suppliers. Flexibility, as it was defined on this study, means supplier’s engineering, manufacturing and procurement capability to fulfill the demand and react to changes. Especially with the complex ETO projects there is a high risk for the scope changes even during the manufacturing phase, and then the supplier’s ability to react to these changes is an asset.

6.3 Supplier Selection Criteria

6.3.1 Future requirements

When looking at the “future requirements” table 11 it was noted that the difference between mean scores of the different categories was relatively small (0,35). This can be interpreted so that all the categories are almost equally important. The standard deviation was also much less compared to “past performance” rating, indicating that there is more consensus in the opinion.

6.3.2 Ranking of categories

Last question in the survey was to rank the four categories in order from one to four. The results (table 21) of this question shows clearly that the categories are not equally valued; Quality got 43% and cost 40% of the “votes” for the first place. This is a clear indication that these two categories (quality & cost) should be emphasized more compared to other two (time & flexibility) when selecting potential Contract Partners and evaluating existing ones.

What would be then the right distribution between these four categories? The difference between quality & cost was insignificant (3% of the total votes) so they should be equally weighted. The flexibility category got almost double the votes (11%) compared to the time (6%). This is off course a significant difference, at least in the relative value (45%). However, “quality” and “cost” got together most of the votes (23 + 21 = 44 pcs) compared to time & flexibility (3 + 6 = 9 pcs). This means that if “time” category would have received a single vote from the “flexibility” they would have received almost an even score. So, in this perspective it would be justified to weight the time & flexibility category with even rate.

Now, if the weighting of the different categories would solely base on the results on table 21 and on analyzation on previous paragraph the assessment weighting would look as on table 30 below:

Table 30: Weighting of the categories based on survey ranking question

Category	Weight (%)
Quality	40
Cost	40
Time	10
Flexibility	10

In the theory part we have learned that all the aspects of the supplier selection criteria´s should be considered, but the weighting of the different categories varies for different industries. Weighting as above would practically mean that “quality” and “cost” would define 80% of the Contract Supplier assessment score. This seems to be in conflict against the nature of the ETO projects where, as it was found in the theory, nature of the operations requires on-time deliveries and at least certain level of flexibility in order to cope with the possible changes with the scope of delivery. Further, the result of the table 11 provides an “extreme” view because it is based on the selection of a single category.

6.3.3 Practical recommendations

So, instead of proposing a percentual division of different categories a practical recommendation for the case company would be to further develop the Contract Supplier assessment template already in use by using following steps:

- Group the different aspects of the assessment to four main categories: Quality, cost, time and flexibility
- Align the weighting of the categories with the representatives from the main stakeholders from different functions. Consider to weight quality & cost categories higher than time & flexibility
- Test the template by using the scores on the last assessment
- Implement and develop the weighting further based on the experience

It is also important that the requirements for all the categories are clearly defined and measurable in order to have balanced overview of the supplier selection and assessment. The supplier assessment tool should guide the supplier to concentrate on the areas important for the Case Company. It would be also wise to define “must have” and “nice to have” requirements for the Contract Suppliers to secure that foundation for the effective operations.

6.4 Discussion

6.4.1 Theory

When the idea of this thesis began to shape, the search for research and literature on the topic started. The ETO as a discipline is well researched and covered by the relevant literature, as well as supplier selection generally - however it turned out that very little study has been done on the ETO manufacturing supplier selection. Therefore, the theory research concentrated on studying and combining ETO and supplier selections generally.

A lot of useful material could be found on the importance of the different categories (quality, cost, time & flexibility) in different industries, and as expected the relative importance of the categories varies in different industries. Results of the survey on this thesis revealed that this is also valid in the case company; Quality and cost received by far highest scores when responders were asked to rank the importance of the different categories. Interesting is that these two categories received quite similar scores. However, quality and cost have some level of dependency between each other; high quality requirement can lead higher direct costs with the component and material selection. On the other hand, high quality decreases the indirect costs; warranty claims, additional work, loss of reputation and customer business (Oakland, 2014). These costs can be significant, but sometimes they are "hidden" and not so clearly visible as the direct material costs.

It is important to define what is the product and design quality level needed from the suppliers, because it has an impact on the costs (Oakland, 2014). This depends whether the design is fixed and defined by the purchaser, or does the supplier have the responsibility of the design, and can propose component and material selections? It must be also remembered that quality is not only design & product quality; process and organization quality is at least equally important, and excellence in these areas can bring substantial benefits with reasonable costs (Oakland, 2014). Balance between quality and cost is an endless source for discussion, but companies who can reach a "high-quality" image have a possibility to get a premium price of their products and solutions, even if the cost difference against competitive products might not be that dramatical.

The most interesting part of this research was the ranking results – how would the responders rank the importance of the four different categories. For this part, the Analytical Hierarchical Process (AHP) methodology was also considered. With this method the relative importance of the factors is measured through pair-wise comparisons, and it will give the priorities between these. However, AHP is a sensitive for consistency – that the relation between all the factors needs to be consistent (Saaty, 2008). As this survey was

done remotely and not by interviewing the participants, there would not have been a chance to check and correct possible consistency errors. Therefore, it was decided to go with the simplified model where responders were simply asked to rank the four categories from first to fourth position. The first position nominees were then used as a reference for the relative importance of the categories. This gives off course a very simplified model for defining the relation between different categories, but it clearly showed that the categories are not equally valued. However, Case Company could utilize AHP with limited amount of subject matter experts from different functions when weighting of different categories is defined further.

6.4.2 Background of the responders

The background of the responders influenced the scoring and ranking of different categories, but the differences were not that remarkable. It is natural and understandable that responder´s area of responsibility has an effect to the valuation of the different categories; Salespeople are constantly in touch with the customers and have, or at least should have, best knowledge about the market price and demands, and they are measured by the annual sales so their interest is to have as cost-effective solution or product as possible. Project management & engineering are working closely with the ETO manufacturing suppliers on the design and manufacturing phase and they are measured by the project success, so they tend to put a high value on the flexibility of the supplier´s people and operations. Procurement's task in Supply Chain is to get a lowest possible cost with defined quality level from the supplier base, and they are measured by the year-to-year cost reduction and quality level of the suppliers. It is vital that the selection criteria of the ETO manufacturing suppliers is a combination of these, and not dictated by single function´s viewpoint.

Challenge with the survey was the fact that almost 50% of the responders are based in Finland. The reason is that major part of the functions responsible of the operations around ETO activities in Case Company are locating in Finland, excluding sales function. This needs to be noted - but on the other hand the responder's selection was focused

on the personnel who are working directly or indirectly with the assessed ETO manufacturing suppliers. This was to ensure that the gathered data is relevant for this research and for the Case Company. Another challenge was that 50% of the responders are working on the sales function, but their geographical location is distributed around EMEA area. There is a reasonable amount of salespeople also in Finland, so in that extent the results from the sales organization is valid for the whole EMEA area with good geographical distribution.

6.4.3 Further research

When looking at other research done around the supplier selection dilemma, there can be found similarities and differences compared to the approach and results on this paper. For example, a research done by Mikhail Gennady Shalygin raises the flexibility together with quality and cost as one of the supplier selection criteria, however the selection methodology presented in the research is based only on comparison of quality and cost. Quality is defined as a product characteristic and the emphasized product or service features are compared against the product cost (Shalygin, 2018). This is somehow narrow approach but can work with simple commodity products or services. With more advanced products or services, like ETO, the supplier selection criteria should be comprehensive and include also other aspects than only quality and cost.

Another research from 2019 raised a very interesting and actual supplier selection criterion; Resilience and disturbance management. According to research supply chains are vulnerable to disruptive events like “natural disasters, human-made attacks and common failures due to growth of global supply alternatives and strategic outsourcing” (Hosseini, ym., 2019). This was experienced during Japanese earthquake and tsunami in 2011, and recently during COVID-19 crisis. A geographical concentration of certain material and components suppliers have caused a shortage of parts and disrupted the supply chain functionality. The research presents a solution for resilient supplier selection with model to compute the likelihood of different disruption scenarios. Naturally higher resilience leads to higher cost if purchaser wants to keep multiple suppliers for certain

components or build up a surplus capacity (Hosseini, ym., 2019). The model introduced in the research can be used as a decision-making tool when comparing two aspects: resilience and costs. This is a very narrow approach, and leaves the other aspects introduced on this final thesis, intact. However, as resilience can be very critical decision factor with the suppliers it would be recommendable to introduce this aspect to the Case Company´s ETO supplier selection criteria, either separately or by merging it to the existing supplier assessment methodology. Flexibility can be seen at least partly related to the resilience, at it is by nature supplier´s ability to respond to changes and alter the manufacturing output.

6.4.4 Further research possibilities

Could the survey method used on this research be used in other case companies and industries? Why not – although there is a chance that the same first two categories will come up again: Quality and cost. Those seem to be the main themes where companies are balancing all the time. Same time, we should not forget one of the main issues found with the theoretical research of the ETO projects; Flexibility. This can be a decisive factor when the competition with the cost and quality is quite even. With the flexibility the companies and their suppliers can make a difference in front of the customer – being it a flexibility of the personnel, operations, or processes. In the world of even more intense competition, it is those small things that customer gets in flexible manner that can be a decisive factor for winning new customers and keeping the existing ones – therefore we should never forget the power of the flexibility in all its forms (Ertis, 2016).

The ETO Manufacturer supplier assessment in the Case Company is based on the scoring of the different criteria, and the criteria are selected specifically for the ETO Manufacturer Suppliers and are based on the experience and evolution of the assessment. However, there are also more sophisticated & scientific methods available for selecting the criteria for supplier selection. These were presented by a literature review in “Journal of Industrial Engineering and Management 2018”. These methods can be based on Delphi, Statistical, multi criteria decision making (MCDM) and mixed methods

(Ristono;Pratikto;Purnomo;& Tama, 2018). Generally, the target with these methods is to find out what are the most critical criteria for selecting suppliers, and this is achieved by requesting the responders to evaluate, rank or select the criteria, depending on the selected method. MCDM method included Analytic Hierarchic Process (AHP), which were considered also for this final thesis. Interesting finding on the paper was the use of "mixed methods", where AHP and statistical methods are combined. Also, Delphi and AHP combination was mentioned. In theory some of these approaches could be used in the Case Company, but as ETO Manufacturer Supplier assessment is only one of the many supplier assessments, it would be recommended to consider the whole supplier assessment as a base for the evaluation and build a foundation for the most important criteria. Weighting of different criteria can then vary depending on the supplier´s scope of supply, i.e. commodities vs. case company specific materials or components.

For the further research it would be recommended to have a similar kind of study with wider responder background, preferably with a company operating in similar business, if not the same company. It would be highly interesting to compare the results in the different studies, and to see if those differ from each other. This would bring more knowledge on the specific area of the ETO supplier selection. This might be even an area for the further study for the Doctor degree, who knows?

7 Summary

Literature review on this research revealed that ETO manufacturing supplier selection criteria can be divided to four different main categories; Quality, cost, time and flexibility. This finding was used to create a survey on the case company by categorizing the Case Company´s existing supplier assessment methodology and create relevant, concrete questions to case company personnel. Results of the survey was used to find out whether the four categories are ranked equally or are there differences on the weighting of different categories. Results showed clearly that two categories, quality and cost, are ranked higher by the responders than the time and flexibility. It was also found out that the responders weighted categories somewhat differently, depending on the function they are working, but differences were not statistically significant.

Based on the results of this research it is recommended that the Case Company develops the ETO manufacturing partner selection criteria further by having different weighting between the selection categories. The exact weighting of the categories was left open, and it needs to be done in co-operation with different stakeholders in the Case Company. It is also recommended to perform similar survey for the same target group at later phase to find out whether the results show a positive or negative development.

References

A guide to the project management body of knowledge (PMBOK guide) (Osa/vuosik. 6). (2017). Newtown Square, Pennsylvania, USA: Project Management Institute.

Addo-Tenkorang, R.;Kantola, J.;Helo, P.;& Shamsuzzoha, A. (2016). *Supply Chain Strategies and the Engineer-to-Order Approach.* Hershey: Business Science Reference (an imprint of IGI Global).

Ajam, M. (2017). *Project management beyond waterfall and agile.*

Alp, N. (2012). Scope management and change control process study for project-based companies in the construction and engineering industries. *2012 Proceedings of PICMET '12: Technology Management for Emerging Technologies*, (ss. 2427 - 2436). Chattanooga.

Bagherpour, M. (2010). A successfull project cost management system: Basic requirements, challenges, and obstacles to implementation. *Cost Management; Boston, 24*(5), 15-20.

Basu, R. (2014). Managing quality in projects: An empirical study. *International Journal of Project Management, 32*(1), 178-187.

Cagno, E.;Micheli, G. J.;& Trucco, P. (2012). Eco-efficiency for sustainable manufacturing: an extended environmental costing method. *Production Planning & Control, 23*, 134-144.

Cheng, L.-C.;& Carillo, E. (2012). Assessing supplier performances under partnership in project-type environment. *Industrial Management and Data Systems, 112*, 290 - 312.

Conforto, E. C.;& Amaral, D. C. (2016). Agile project management and stage-gate model—A hybrid framework for technology-based companies. *Journal of Engineering and Technology Management, 40*, 1-14.

de Araujo, M.;Alencar, L.;& de Miranda Mota, C. (April 2017). Project procurement management: A structured literature review. *International Journal of Project Management, 35*(3), 353 - 377.

Eldin, N. N. (Feb 2005). The effect of Early Freezing of Scope on Project Schedule. *Cost Engineering, 47*(2), 12-18.

Ertis, N. (2016). Are Agile Organization Models The Future. *HR Strategy and Planning Excellence Essentials*.

Eskerod, P.;& Huemann, M. (18. January 2013). Sustainable development and project stakeholder management: what standards say. *International Journal of Managing Projects in Business*, 36-50.

Eskerod, P.;Huemann, M.;& Savage, G. (January 2016). Project Stakeholder Management - Past and Present. *Project Management Journal, 46*(6), 6-14.

Grabenstetter, D.;& Usher, J. (1. January 2015). Sequencing jobs in an engineering-to-order engineering environment. *Production & Manufacturing Research, 3*, 201 - 217.

Handfield, R. B.;Monczka, R. M.;Larry, G. C.;& Patterson, J. L. (2009). *Sourcing and Supply Chain Management.* South-Western.

Helo, P.;Tuomi, V.;Kantola, J.;& Sivula, A. (June 2019). *Quick guide for Industrial Management thesis works.* Vaasa: Vaasan Yliopisto.

Hoosmand, Y.;Köhler, P.;& Korff-Krumm, A. (2016). Cost Estimation in Engineer-to-Order Manufacturing. *Open Engineering, 6*, 22-34.

Hosseini, S.;Morshedlou, N.;Ivanov, D.;Sarder, M.;Barker, K.;& Al Khaled, A. (July 2019). Resilient supplier selection and optimal order allocation under disruption risks. *International Journal of Production Economics, 213*, 124-137.

Iakymenko, N.;Romsdal, A.;Semini, M.;& Strandhagen, J. (2018). Managing engineering changes in the engineer-to-order environment: challenges and research needs. *IFAC PapersOnLIne, 51*, 144-151.

Jain, A.;Jain, P.;Chan, F. T.;& Singh, S. (2013). A review on manufacturing flexibility. *International Journal of Production Research, 51*(19), 5946-5970.

Johnsen, S. M.;& Hvam, L. (9. May 2018). Understanding the impact of non-standard customisations in an engineering-to-order context: A case study. *International Journal of Production Research*, 1-15.

Khan, A. (2006). Project Scope Management. *Cost Engineering, 48*(6), 12-16.

Krajewski, L. J.;Malhotra, M. K.;& Ritzman, P. L. (2016). *Operations Management.* Essex: Pearson Education Limited.

Mello, M. H.;Strandhagen, J. O.;& Alfnes, E. (2015). Analyzing the factors affecting coordination in engineering-to-order supply chain. *International Journal of Operation & Production Management, 35*, 1005 - 1031.

Muriana, C.;& Vizzini, G. (2017). Project risk management: A deterministic quantitative techinque for assessment and mitigation. *International Journal of Project Management*, 320-340.

Muriana, C.;& Vizzini, G. (2017). Project risk management: A determistic quantitave technique for assessment and mitigation. *International Journal of Project Management*, 320-340.

Nahod, M.-M. (June 2012). Scope Control Through Managing Changes in Construction Projects. *Organization, Technology & Management in Construction, 4*(1), n/a.

Nastase, G. (October 2013). General aspects of project quality management. *Quality - Access to Success, 14*, 91-93.

Oakland, J. S. (2014). *Total Quality Management and Operational Excellence* (Osa/vuosik. 4). New York, NY, US: Routledge.

Oliveira, A.;& Gimeno, A. (2014). *Managing Supply Chain Networks: Building Competitive Advantage in Fluid and Complex Environments.* New Jersey: Amy Neidlinger.

Oshri, I.;Kotlarsky, J.;& Willcocks, L. (2009). *The handbook of global outsourcing and offshoring.* Basingstoke: Palgrave MacMillan.

Pollack, J.;Helm, J.;& Adler, D. (2018). What is the Iron Triangle, and how has it changed? *International Journal of Managing Projects in Business*, 527-547.

Rane, S. B.;Narvel, Y.;& Bhandarkar, B. M. (2019). Developing Stragegies to improve agility in the project procurement management (PPM) process. *Business Process Management Journal*, 257-286.

Ristono, A.;Pratikto;Purnomo, B.;& Tama, I. (2018). A literature review of criteria selection in supplier. *Journal of Industrial Engineering and Management, 11*(4), 680-696.

Saaty, T. L. (2008). Decision making with the Analytic Hierarchy Process. *International Journal of Services Sciences*, 83-98.

Samakova, J.;Babcanova, D.;Hrablikchovanova, H.;Mesarorova, J.;& Sujanova, J. (01. September 2017). Using the Communication Methods, Tools and Support During Management of Project Communication in Industrial Manufacturing Enterprises. *Research Papers. Faculty of Materials Science and Technology. Slovak University of Technology in Trnava, 25*, 51-62.

Serrano, P.;& Pinto, J. K. (2015). Does Agile work? A quantitative analysis of agile project success. *International Journal of Project Management*, 1040 - 1051.

Shalygin, M. G. (30. November 2018). Methof of supplier selection by means fo correlation of quality and cost characteristics of products. *Quality Innovation Prosperity, 22*(3), 27-35.

Tavakol, M.;& Dennick, R. (2011). Making sense of Cronbach´s alpha. *International Journal of Medical Education*, 53-55.

Tjahjana, L.;Dwyer, P.;& Habib, M. (2009). *Program Management Office Advantage.* Amacom.

Vaagen, H.;Kaut, M.;& Wallace, W. S. (16. September 2017). The impact of design uncertaintity in engineer-to-order project planning. *European Journal of Operational research*, 1098-1109.

Ward, P. T.;McCreery, J. K.;Ritzman, L. P.;& Sharma, D. (1998). Competitive priorities in operations management. *Decision Sciences, 29*(4), 1035 - 1046.

Wilner, O.;Powell, D.;Gerschberger, M.;& Schonsleben, P. (2016). Exploring the archetypes of engineering-to-order: An emprical analysis. *International Journal of Operations & Production Management, 36*(3), 242-264.

Yang, L.-R. (January 2013). Key practices, manufacturing capability and attainment of manufacturing goals: The perspective of project/engineering-to-order manufacturing. *International Journal of Project Management, 31*, 109-125.

Appendices

Appendix 1. Survey questions

Thank you for taking time to contribute in this survey!

This survey is a part of a Master´s Thesis and the aim is to evaluate EMEA Contract Supplier´s past performance and future requirements for engineering-to-order (ETO) cabinet deliveries. Respondents are selected from different functions of the company. All answers will be handled as anonymous.

You are selected on the assumption that you have at least some experience of the services of the EMEA Contract Suppliers (opportunity or project delivery phase). You don´t need to be in direct contact with Contract Suppliers to be able to answer this survey.

When you are answering the questions please think and evaluate solely the performance & delivery of the **Contract Suppliers**. Danfoss scope & performance is out of scope on this query.

There are totally 30 questions, and based on the reference group testing answering to this survey should take no more than 15 minutes.

If you have any questions or problems with this survey please contact me.

Thanks,

J-P Suomela

juha-pekka.suomela@danfoss.com

Global Center of Excellence

Part 1: Questions about your background (total 4)

Which country you are located in?

(1) ❑ AE (United Arab Emirates)
(2) ❑ AT (Austria)
(3) ❑ CR (Croatia)
(4) ❑ CZ (Czech)
(5) ❑ DE (Germany)
(6) ❑ DK (Denmark)
(7) ❑ ES (Spain)
(8) ❑ FI (Finland)
(9) ❑ FR (France)
(10) ❑ NL (Holland)
(11) ❑ NO (Norway)
(12) ❑ PL (Poland)
(13) ❑ RO (Romania)
(14) ❑ RU (Russia)
(15) ❑ SE (Sweden)
(16) ❑ UK (United Kingdom)

Which function you are working on?

(2) ❑ Aftermarket Service
(6) ❑ Center of Excellence
(5) ❑ Marketing
(4) ❑ Product Management & Development
(1) ❑ Sales
(3) ❑ Supply Chain

What is your job title / position?

_____

How many years have you worked in Danfoss?

(1) ❑ Under 1 year
(2) ❑ 1 - 5 years
(3) ❑ 5 - 10 years
(4) ❑ 10-20 years
(5) ❑ Over 20 years

Your age?

(1) ❑ 20 - 29
(2) ❑ 30-39
(3) ❑ 40-49
(4) ❑ 50-59
(5) ❑ 60 or older

Part 2 - Rating of Contract Supplier past performance (total 13 questions) - main categories are Quality, Cost, Time & Flexibility.

You can rate only one supplier so if you have worked with both of them please select the Contract Supplier you have more experience of.

Which Contract Partner you are evaluating?

(1) ❑ Contract Partner #1

(2) ❑ Contract Partner #2

Past performance of the Contract Supplier related to **Quality**:

Deliveries by the Contract Supplier has very low defect rate

Strongly disagree	Disagree	More or less disagree	Undecided / neut-ral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Deliveries by the Contract Supplier meets customer specification

Strongly disagree	Disagree	More or less disagree	Undecided / neut-ral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Testing (FAT) done by the Contract Supplier is adequate and professional

Strongly disagree	Disagree	More or less disagree	Undecided / neut-ral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Past performance of the Contract Supplier related to **Cost**:

Contract Supplier provides a right cost level to be competitive in the market

Strongly disagree	Disagree	More or less disagree	Undecided / neutral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Deliveries by the Contract Supplier has very low-quality costs

Strongly disagree	Disagree	More or less disagree	Undecided / neutral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract supplier is able and willing to provide improved year-to-year cost development

Strongly disagree	Disagree	More or less disagree	Undecided / neutral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Past performance of the Contract Supplier related to **Time**:

Contract Supplier provides competitive delivery time

Strongly disagree	Disagree	More or less disagree	Undecided / neutral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier delivers always on time and right amount

Strongly disagree	Disagree	More or less disagree	Undecided / neutral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Response (project support, quotes) from the Contract Supplier is fast and relevant

Strongly disagree	Disagree	More or less disagree	Undecided / neutral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Past performance of the Contract Supplier related to **Flexibility**:

Contract Supplier has necessary engineering capability (competence, resources, tools) for design engineering

Strongly disagree	Disagree	More or less disagree	Undecided / neut-ral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier has necessary manufacturing capability to fulfill market demand (volume, mix)

Strongly disagree	Disagree	More or less disagree	Undecided / neut-ral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier has necessary procurement capability for securing the delivery and reacting to changes

Strongly disagree	Disagree	More or less disagree	Undecided / neut-ral	More or less agree	Agree	Strongly agree
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Part 3 - Rating the future expectations of the Contract Supplier´s performance (total 12 questions) in the main categories (Quality, Cost, Time & Flexibility).

Scale is from "much lower importance" to "much higher importance" compared to today.

The future expectations of the Contract Supplier related to **Quality**:

Deliveries by Contract Supplier has very low defect rate

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Deliveries by Contract Supplier meets customer specification

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Testing (FAT) done by the Contract Supplier is adequate and professional

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

The future expectations of the Contract Supplier related to **Cost**:

Contract Supplier provides a right cost level in order to compete in the market

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Deliveries by Contract Supplier has very low-quality costs

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier is able and willing to provide improved year-to-year cost development

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

The future expectations of the Contract Supplier related to **Time**:

Contract supplier provides competitive delivery time

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier delivers always on time and right amount

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Response (project support, quotes) from the Contract Supplier is fast and relevant

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

The future expectations of the Contract Supplier related to **Flexibility**:

Contract Supplier has necessary engineering capability (competence, resources, tools) for design engineering

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier has necessary manufacturing capability to fulfill market demand (volume, mix)

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Contract Supplier has necessary procurement capability for securing the delivery and reacting to changes

Much lower importance	Lower importance	Somewhat lower importance	Same as today	Somewhat higher importance	Higher importance	Much higher importance
(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Part 4 - Ranking the relative importance of Quality, Cost, Time and Flexibility dimensions with Contract Supplier performance.

Please rank the order of importance with Contract Supplier (1st = most important, 4th = least important)

	Quality	Cost	Time	Flexibility
1st	(2) ❑	(3) ❑	(4) ❑	(5) ❑
2nd	(2) ❑	(3) ❑	(4) ❑	(5) ❑
3rd	(2) ❑	(3) ❑	(4) ❑	(5) ❑
4th	(2) ❑	(3) ❑	(4) ❑	(5) ❑

The survey is now completed - Many thanks for your feedback!

BR,

J-P Suomela