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TOTAL COST OF OWNERSHIP IN PROJECT PROCUREMENT

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ABSTRACT

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In this thesis the term TCO (Total Cost of Ownership) is introduced and presented in context of project procurement for equipment packages. Project procurement is usually part of an EPCM-contract made between the client and the EPCM-contractor and the contractor takes responsibility of the procurement actions. The current state of including TCO in procurement is not inclusive to all industrial business lines, which are the pulp and paper industry, chemicals and bio-refining industry and mining and metals industry. There are differences based on industry and equipment sizes where in most of the cases, investment cost is the most defining factor in purchasing resolutions. In order to get a cross-section of the situation and determine the needs and expectations for the TCO, interviews and questionnaires were prepared and sent to the representatives of the industries: to clients, consulting procurement specialists and the suppliers. Based on the results, clients and suppliers are expecting early commitment from the EPCM-contractor to the project procurement. In order to create a tool for TCO in project procurement, a framework is presented.

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Tässä diplomityössä esitellään termi TCO (Total Cost of Ownership) kokonaiskustannukset. Termi esitetään tässä työssä projektihankintoihin liittyvänä osa-alueena, laitepakettien hankinnoissa. Projektihankinnat ovat yleensä osa EPCM-sopimusta, joka solmitaan asiakkaan ja EPCM-toimijan välillä, jolloin konsulttiyritys ottaa vastuun hankintojen johtamisesta. Tilanne tällä hetkellä on se, että kokonaiskustannuksia ei oteta tasaisesti huomioon kaikilla teollisuudenaloilla, joita ovat tarkasteltavassa kohteessa: sellu- ja paperiteollisuus, kemianteollisuus ja biojalostusteollisuus sekä kaivos- ja metalliteollisuus. Eroja on teollisuusalojen välillä sekä siinä minkä kokoisesta hankinnasta on kyse, ja yleinen ilmiö on että hankintapäätökset tehdään pääosin perustuen hankintahintaan. Jotta saatiin hyvä läpileikkaus nykytilanteesta sekä tarpeista mitä TCO:n määrittämiseen on, järjestettiin haastatteluja ja tehtiin kyselylomakkeet, joita lähetettiin hankinnasta vastaaville tahoille: sekä asiakkaille, hankintaspesialisteille että toimittajille. Tulosten perusteella asiakkaat sekä toimittajat toivovat mahdollisimman aikaisessa vaiheessa EPCM-toimijan panostamista projektin hankintoihin. Jotta voidaan jatkossa luoda työkalu kokonaiskustannusten paremmalle määrittämiselle, työssä esitetään viitekehys niiden huomioimiseen projektihankinnoissa.

PREFACE

This thesis is written for a leading consulting and engineering company in Finland Oy between June and November 2018. I am grateful for my supervisor, Professor Timo Pirttilä for the guidance and good advice along the way. I also want to thank my advisor for guidance and good brainstorming meetings that we had that inspired me to work harder. I am grateful for our amazing procurement team, especially my superior who gave me the idea for this topic, and also gave me opportunity to concentrate and spend a lot of valuable working time on this thesis and supported me all the way. There were so many experienced and competent colleagues and experts that I had the honor to interview and who gave me many ideas and contact details to go forward with. I am really lucky to be part of such a good work community that we have at our work place.

More than anything I want to thank my dear family and my friends for supporting me during my studies, it really hasn't always been an easy way, but with their support I was able to fulfill this long time target.

Vantaa, November 28th, 2018

Minna Lahti

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ABBREVIATIONS

CAPEX	Capital Expenditures
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement and Construction Management
IBG	Industry Business Line (in Case Company)
IRR	Internal Rate of Return
LCC	Life Cycle Cost
MRO	Maintenance, repair, and operating supply items
NPV	Net Present Value
OPEX	Operational Expenditures
RFT	Request for Tender
SRM	Supply Risk Management
SS	Supplier Selection
TCO	Total Cost of Ownership

1 INTRODUCTION

1.1 Background

In project procurement it is common to emphasize the significance of the price, but there are several other factors and costs that have an impact to the decision of the purchase. For instance a cheap cooling tower might not produce the capacity of a more expensive one. Costs caused by extra service hours and shut downs will incur much higher total expenses for the operation. Therefore it is more important to concentrate on total effects of the costs in the long run, rather than the direct cost of the purchase. However it is not that simple to evaluate and measure these cost effects.

Procurement work at Case Company is part of almost every single project and it has a significant role both in project schedule and budget and of course in serving the client. When a client hires the Company to be their EPCM-contractor for a construction or expansion project, they expect to get a full service complex including engineering, procurement and construction management for the entire project. The Company is aiming to serve their clients even better in the future and by offering them more diverse service in procurement by taking TCO and life cycle cost contemplation into routine work will definitely be an ensuring advantage.

1.2 Aim and objectives of the thesis

The purpose of this master's thesis is to find answers to question: **how can TCO as a concept be adapted in project procurement in the Case Company?** The aim of this work is to create ideas for Case Company's procurement and develop new ways to serve clients by offering them more information and back up in procurement resolutions. The understanding of the TCO as a concept and the cost

effects and influences during the whole life cycle of a product is essential in order to create improved service for the clients. By doing this, Case Company can provide added value for the client and enhance its competitive position. As a result, a framework for the implementation is created in this thesis as a part of problem-solving solution.

1.3 Framing of the thesis

This work is framed so that the main focus is in procurement of equipment packages, therefore services and contractor works are not included. Equipment package in this description comprises procurement of a single item such as a pump or a tank or a bigger package of equipment or unit like a distillation unit with several items included in one equipment delivery package. Reason for this framing is to get first a clear picture of the term TCO in procurement and then adapt it to daily procurement work, and this is most convenient when dealing with equipment packages. They are easily defined units and calculating their life cycle and costs is much simpler than it is with wider complexes such as piping contracts etc. However when understanding of TCO in equipment packages is profound and practices are developed to every day works, it is possible to extend procedures to all forms of procurement.

This work is also framed so that the concept of TCO is presented and introduced to project procurement in theory and adapted examples of practice and how to work towards the TCO tool, the development and execution of any templates or calculation is excluded.

1.4 Thesis implementation

In order to find a way to utilize TCO in project procurement the current state of equipment life cycle contemplation and grounds for equipment procurement and

tender comparisons is described and the needs for TCO are studied. For the current state analysis, Case Company's procurement personnel are interviewed from the main industry sectors, which are: pulp and paper department, chemicals and bio refining department and mining department. The Case Company is acting as a consult to serve clients; it is logical to study the opinions and needs from the biggest clients. Case Company's procurement managers are interviewed to get their advice for right research questions and right contact persons. Results of the surveys are used for development and procedures for TCO use in Case Company procurement in projects. After gathering sufficiently theoretic information about the TCO, the surveys are created and implemented during October and November 2018. Surveys will be done by interviewing and by sending a questionnaire by email, the created forms are attached to this thesis in Attachment 1 and 2.

Based on the results of the questionnaires an implementation frame is created to adapt the concept to the reality of project procurement. With the help of the created method, a tool for determining TCO or LCC analysis can be created to include in the pre-design phase for cost estimates and in design phase for implementation of projects in future. By using that tool in future as a default part of any project procurement, clients will be served better and they will be given more information of the procurement's life cycle lasting costs and see further ahead in their own operations.

1.5 Structure of the thesis

Thesis is formed of 10 chapters.

In chapter 1 the thesis is described and the aim of the work is explained. This work is done for the Case Company and needs for this work is exposed and opened.

In chapter 2 the Case Company as a working environment is introduced and the procurement procedures and practices in literature level are presented. Project work and the different project types (EPC, EPCM) are presented.

In chapter 3 the definitions and characters of TCO as a concept are described. TCO can be connected to many different contexts and its connection to procurement is the matter of substance in this work. Also the benefits of the TCO point of view are presented. Different ways of making good use of TCO in procurement are handled. TCO as a tool and contemplation is illustrated in various ways and as a beneficial example for projects. The possible challenges and factors that must be taken into consideration are handled and described. It is also emphasized how to be aware of typical challenges in project procurement work and budget thinking.

In chapter 4 a framework for understanding total cost of ownership is presented in a table form and made visually clear how to approach the TCO contemplation as an example. Also a procurement total cost counting approach is presented as an option for the concept.

In chapter 5 the Total Cost of Ownership implementation is handled in practical examples from literature, and also the different aspects in implementing the contemplation to an organization to be aware of. A total cost of the supply chain from sub suppliers to final client is presented. There are many points to think through when making a calculation based on TCO, among others the awareness of the risks in calculating and their importance.

In chapter 6 the supplier selection, connected with supply risk issue and TCO is presented. When selecting a supplier for the equipment package there are several important points to take into consideration and that have an impact on the total cost.

In chapter 7 the aspect of cost accounting is connected to TCO as it naturally is in all cost based thinking. Behind the TCO methodology is often money and savings and that is handled in terms of savings and the concept of life cycle cost (LCC).

In chapter 8 the present state of TCO and Life Cycle Cost contemplations are described in the Case Company. This chapter also presents the study part of this thesis and reveals how the surveys were implemented and how the information and results were gathered. Also the results of the questionnaires and interviews are presented. According to the results, the most important TCO factors are picked from the questionnaires and interviews.

In chapter 9 the development of the framework is presented based on the study results. The framework itself is illustrated and described. By using the framework for TCO implementation in project procurement, a tool or template can be developed in future use.

In chapter 10 is a summary of the thesis.

2 PROJECT PROCUREMENT AT THE CASE COMPANY

The Case Company that this thesis is made for is highly valued and has operated for decades in many industrial fields in Finland and abroad. The company has been growing and developing over the years and today has thousands of people working for it, backed up with a strong history and rich heritage. After several years of reshaping, the company is better positioned to compete. Vision is based on three pillars: trusted partner, smart solutions and connected teams. The main idea is – the connected company, which is the engine for growth. Mission is about contributing sustainable value to clients and society.

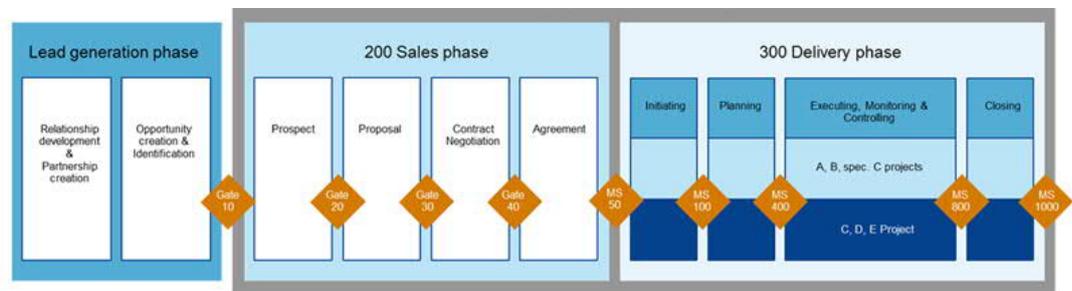
In following chapters the Case Company's project work is described in more detail and the different types of projects are presented shortly. To get a clear picture of the procurement part of the project, the procurement flow chart and process are presented visually and explicitly.

2.1 Project types and project life cycle

The most common project execution methods in industrial projects are EPC (Engineering, Procurement and Construction) and EPCM (Engineering, Procurement and Construction Management). EPC-contract is called a lump sum turn-key contract. In the EPCM-execution method engineering, procurement and construction management, as well as project management services, are from one source. EPCM service provider takes care of services from project planning, engineering and coordination, to construction management within a budget and a schedule agreed together with the owner. This means that clients have a single contact partner and there is no need to create separate organizations for project interfaces. When this execution method is applied, Case Company is acting as an

EPCM contractor and the client is a project owner. (Loots & Hensie 2007, 8-9, 12-13.)

Case Company has a lifecycle of project (Picture 1) that describes the life of a typical project. It can also be seen as a supply chain of the project work. Lifecycle is divided into phases according to project status. First is the lead generation phase where relationship to the potential client is developed and partnership is created, also clients' needs are been surveyed so that the project can be created to meet them. The second phase is sales phase where the prospect is found and client's needs are transformed into a project, that can be then proposed to the client which then will lead to contract negotiation and finally to an agreement. The final phase is delivery phase where the project is initiated, planning and actions, such as procurement, are started and project will be executed, monitored and controlled until it is closed.



Picture 1. Case company project life-cycle (Project Management Guidelines in a Nuthsell 2012).

2.2 Project Procurement Management

It has been described in Case Company's guidelines for procurement that the basic objective of Procurement Management Services is to purchase equipment, material and services, necessary to meet the project's technical specifications and to ensure that they are delivered in accordance with the overall project schedule and contract in the most effective manner and the deliveries fit to the purpose.

Case Company's Procurement Services are focused on providing equipment, materials and services for the projects through efficient procedures and tools that assure both the minimum costs and risks and the maximum benefits for projects.

In all project the common procedure is to prepare a Project Procurement Manual with procurement services included. This applies to the following service types:

- Engineering, Procurement and Construction Management (EPCM)
- Engineering, Procurement and Construction (EPC)

In all EPCM and Operation and Maintenance project cases the client will be responsible for the commercial, financial and legal aspects of the purchasing. The client will pay the invoices directly to the suppliers and contractors, but the payment control i.e. checking and verifying the correctness of the invoices can be handled by Case Company's Procurement team.

In all EPC projects Case Company will be responsible for the agreements and will pay the invoices except if otherwise agreed. The Procurement Manual will be part of the Project Management Plan. The procurement services are typically executed by one specific Case Company business unit. Cooperation with other business units can be beneficial for the client and for the Company. Basic organizational structures of EPC and EPCM organization models are presented in figure 1.

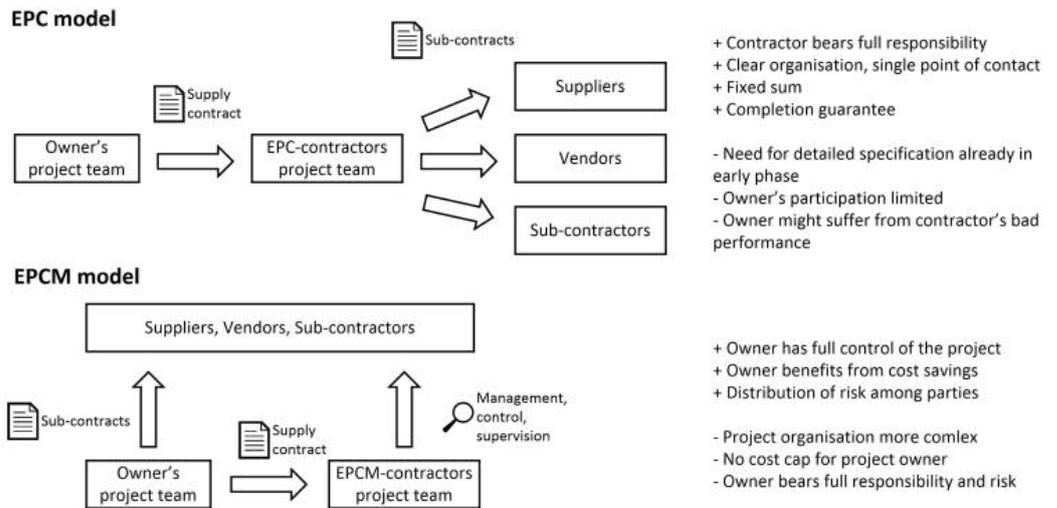


Figure 1: Basic organizational structures of EPC and EPCM organization models, with their corresponding pros and cons presented. (Kimmons, R.1990)

The key responsibilities between the three main partners (EPCM-contractor, Client and Suppliers) are presented in the table of procurement roles (Picture 2) when implementing a project where the Case Company is appointed as the clients EPCM Consultant. The key responsibilities are defined for the main phases of a project i.e. engineering, procurement and construction. In some cases the Company may be required to carry out basic engineering to develop system specifications as well as detailed engineering services. In other cases, the basic engineering may be supplied by the client. These aspects must be clearly defined when discussing with the client. (Niemitalo 2012, 2)

	EPCM-CONSULTANT	CLIENT	CONTRACTORS/SUPPLIERS
PROCUREMENT	Prepares tendering process and documents for client, co-ordinates procurement expediting & inspection services and negotiations processes	Decides on, negotiates and enters into purchase agreements	Enters into purchase agreements with client

Picture 2: Procurement roles (Case Company EPCM Services Guidelines)

2.3 Procurement Process and procurement flow chart

Project procurement tasks begin at very early stage of project as procurement is straight connected to overall project budget and the overall project schedule. At first the purchasing packages are presented to procurement team and total number of equipment and service packages is determined. Defining of the long lead items defines the procurement schedule and number of packages defines the resources. It is important at this stage to get inside the clients mind to see what way they really expect the EPCM-contractor to purchase for them. When this is paid attention to at the earliest stage as possible, it is the most beneficial detail when the project proceeds.

It is described in the Case Company's Service Guideline (2016, 33-34) that technical specification requirements, working standards and quality factors must be decided before starting any design work. Commercial specifications and terms are also decided at this stage and the suitable contract model is chosen. There is no absolute way of working when it comes to selecting a contract model. Very often the models come from the client. Typically, contract models in large industrial plant projects include: purchase contracts for supply with or without erection work, purchase orders, blanket order agreements or specific purpose equipment, unit price contracts, call-off orders, MEI (mechanical, electrical and instrumentation) and civil work contracts and construction manager's instructions (extra work orders at site). (Vehviläinen 2006, 125)

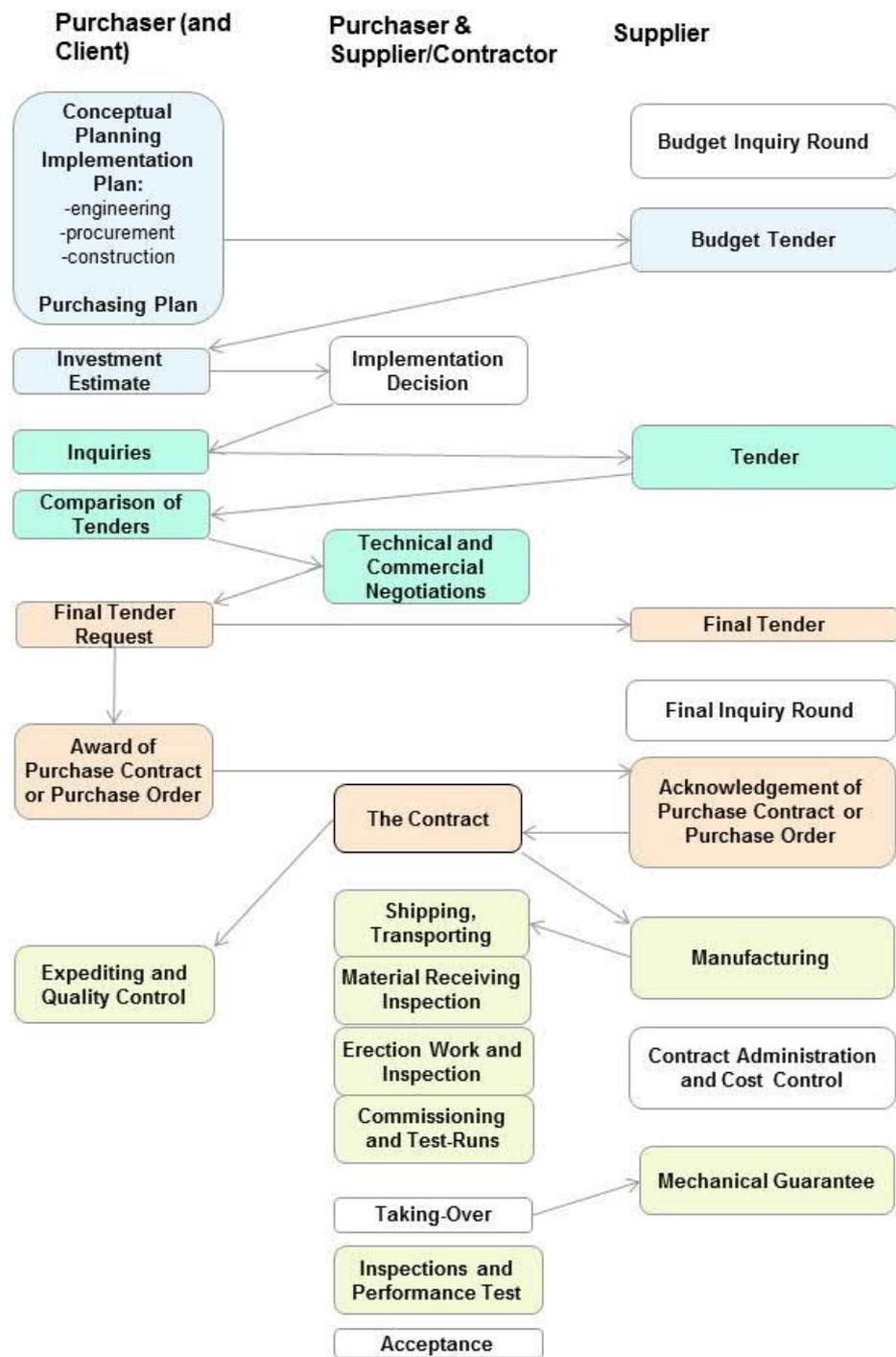
After the Company has prepared the documents, completeness of the contract technical specifications and commercial terms is reviewed. If the documentation is approved by the client, the process can begin. The next step is to manage the pre-award procurement process, which will include:

1. Preparing a list of suppliers in accordance with the clients expectations
2. Preparing the procurement schedule
3. Issuing requests for tenders and track the bidding process with a template build for the project

4. Preparing commercial and technical evaluation, requesting the engineering responsible for support for technical evaluation, to ensure conformity between technical and commercial proposals. TCO-analysis of a product would be connected to this phase of the process, where as a part of commercial and technical evaluation, client received an accurate comparison of the total cost of the products.
5. Supporting and arranging (including engineering and site management), and participating with the client in the commercial negotiations. Clients will take responsibility to finalize any commercial and contractual aspects.
(Case Company Service Guidelines 2016, 33-34)

Procurement work procedures can be presented for example with a visual procurement flow table presented on the next page (Picture 3). This presentation comprises all of the procurement phases for purchased items: a budget tender inquiry round, a tender inquiry round and the final tender round. The budgetary inquiry round is carried out for instance to make a cost estimate for a pre-feasibility study project. The tender inquiry round is processed in an investment project (EPC, EPCM) in order to make purchases for the project. In some cases there is no need for a final tender round, but it is always needed whenever there is a competition with the two to three final suppliers who are all technically and commercially comparable. The final round is resulted with the selected supplier and continues to making contracts.

After the selection of the supplier, follows managing the post-award procurement process, which will include arranging of kick-off meetings with suppliers and contractors if necessary and preparing technical and commercial documentation for contracts and revisions. Purchase orders and purchase agreements are administrated and followed by expediting of the delivery and all the deliverables related. Usually Case Company has agreed to perform desk expediting that will not include visiting workshops and making inspections but just controlling the quality of documents and delivery within schedule adherence.



Picture 3. Chronological procurement flow

3 TOTAL COST OF OWNERSHIP (TCO)

The term TCO is used very often in context of cost efficient business thinking and when making long-term cost forecasts and simply adding cost awareness to organizations. TCO contemplation can be adapted in various levels, both in complex and large and in small and simple, but the main principle is always the same. What this means is that the product life cycle is essentially the main point of the definition and TCO is not just about the money but also about sustainability and understanding the concept of extended product life. In this chapter the concept is introduced. TCO issues associated with purchases are expanded in the following chapters.

3.1 The concept of TCO and adapting it to procurement work

The concepts of total cost, life cycle costing, product life cycle costs and total cost of ownership are all related. These concepts all suggest that procurement managers adopt a long-term perspective, not a short-term, initial-price perspective, for the accurate valuation of buying situations. (Ferrin & Plank 2002, 18)

Three ideas support all of these procurement valuation constructs. First, cost must be examined from a long-term perspective and should include elements other than initial purchase price. Second, supply managers must consider the impact of other business functions on the valuation of a specific purchase. Finally, to value a purchase situation accurately, a supply manager must understand, and measure, the cost impact of all the activities associated with the purchase. (Ferrin & Plank 2002, 18) The contemplation of the TCO is based on activity based costing (ABC) which means that every single action, mission and work phase can be calculated in terms of time and cost. Total cost of the end product is the sum of

every cost of actions focused on product or within a service. (Iloranta & Pajunen-Muhonen 2012 152–153)

TCO differs from most models that attempt to look at the cost of doing business with a supplier. First, TCO considers a broader spectrum of acquisition costs than do most cost of ownership systems. Second, TCO attempts to look at life cycle costs, which consider costs associated with using a given item, including costs incurred once the item is in use. For example, for capital equipment, post purchase costs involve everything from maintenance, repairs, downtime, and obsolescence through to the ultimate disposal of the asset. For a component or material, total cost includes failure costs of the item once in use, such as warranty claim costs, lost goodwill, replacement, and similar costs. (Ellram 1993, 4)

The concept of TCO can be used in various contexts, for example in cost management and purchasing. External purchases of products and services account a great part of the total costs for most companies. Consequently, significant cost savings can be realized by effectively determining procurement strategies. The total cost of ownership reflects the resources consumed in performing the purchasing-related activities and measures all the costs and benefits of a firm's relationships with its suppliers. It requires an integrated approach of the impact of purchasing decisions on a company's value chain. Just as customer profitability analysis provides the insight that the largest revenue customers may not be the most profitable ones because they may demand excessively costly special treatment and delivery conditions, the total cost of ownership often reveals that the cheapest suppliers may impose additional high costs on the firm because of, for example, high ordering costs, quality problems, discount practices and payment procedures. (Degraeve et al 2004, 51-59)

Total cost calculation requires information calculated for every operation or based on evaluations, so it takes time to perform. On the other hand an accurate and easily construed understanding of different factors' cost effects can be achieved based on the calculation. A significant benefit for a detailed analysis is also deeper learning of the costs. A good calculation can also be used as a template for other total cost calculations in future. (Iloranta & Pajunen-Muhonen 2012, 159)

TCO can be used at various stages in procurement:

- In a business case to assess the costs, benefits and risks associated with the investment
- When assessing different business models, maintenance options or solutions on a comparable cost basis
- To understand the different cost drivers in the life of a procurement
- By a supplier when bidding for a contract to demonstrate the total benefits and value being offered – especially where the investment price is higher than competitors, but the total cost of ownership is lower
- In selecting the best supplier by assessing the comparative life cycle costs of competing bids
- In managing the contract to track actual expenses and income against budget
- As part of a benefits realization exercise.

3.2 Benefits of Total Cost of Ownership

When considering TCO and its advantages in procurement, it's clear that there are several benefits compared to not using TCO contemplation, starting from supplier evaluation phase and ending with equipment services. There are several benefits that will have an impact on daily procurement work and decision making. Table 1 presents the main points which are then explained in more detail in following chapters.

Major benefits are grouped into five categories: benefits associated with performance measurement, decision making, communication, insight/understanding and the support of continuous improvement efforts as presented in Table 1.

Performance Measurement

- Good frameworks to evaluate suppliers
- Concrete way to measure results of quality improvements efforts
- Excellent tool for benchmarking

Decision Making

- Forces purchasing to quantify tradeoffs
- Good basis for making supplier selection decisions
- More informed decision making
- Creates a structured problem-solving environment

Communication

- Excellent communication vehicle between a firm and its suppliers
- A way to get other functions involved in purchasing decisions

Insight/Understanding

- Provides excellent data for trend analysis on costs
- Provides excellent data for comparing supplier performance
- Provides excellent data for negotiations
- Provides critical data for target pricing
- Requires purchasing to develop an awareness of most significant nonprice factors that contribute to TCO
- Provides a long-term orientation by focusing on the big picture

Support Continuous Improvement

- Helps identify where suppliers should focus improvement efforts – drives suppliers to work on the right thing
- Helps identify cost savings opportunities
- Forces a firm to look at internal issues – how their own requirements and specifications may actually increase costs
- Encourages professional growth in purchasing personnel by broadening their perspective

Table 1. Benefits of TCO in procurement work (Ellram, L. M. 1994, 173)

The performance measurement category of benefits includes those that improve the quantitative measurements of supplier performance. It includes such issues as the following: TCO is a good way to evaluate suppliers; TCO provides a quantitative method for measuring the results of supplier performance improvement/quality improvement efforts, and TCO provides an excellent tool for benchmarking. In benchmarking, TCO data can be used to compare suppliers, or to track changes in a supplier's cost performance over time.

TCO also supports improved decision making. TCO forces the quantification of tradeoffs in terms of money. It also provides a good basis for supplier selection decisions, because it provides complete cost data on the important cost issues. Thus, TCO creates more informed decision making, in a structured, systematic way.

TCO can also help improve both internal and external communications for purchasing function. The system provides solid data to communicate to suppliers regarding their performance. It also represents an important way to get others within the firm involved in purchasing decisions- by providing data, or identifying relevant cost considerations.

The depth of the TCO approach also provides important insights and deeper understanding into the true nature of supplier performance. The information developed using TCO regarding a supplier's total costs can be used to track the supplier's costs over time, or to compare with other suppliers. Such detailed information provides excellent data for negotiations, and can help focus target pricing efforts. TCO also helps purchasing personnel develop an awareness of the significant nonprice factors that affect their firm in the case of certain buys. This insight can help in negotiations, and in determining which nonprice cost elements a supplier should provide, and which can be foregone or obtained more economically elsewhere. Finally, TCO provides a better understanding of purchase decisions by taking a long-term, big picture approach. It looks beyond price to explore how purchasing activity affects the firm's total costs both today and in the future.

All of these categories of benefits represent proactive means for purchasing to help continuously improve some aspect of the firm's or the supplier's operations. The last major benefit category includes those benefits specifically aimed at supporting a firm's continuous improvement efforts. By identifying various critical cost elements and their values, TCO helps focus a supplier's efforts on improving the right place. TCO also uncovers cost savings opportunities by highlighting large cost elements. Internally, TCO allows firms to gain an understanding of how their requirements (delivery, inventory, unique specifications etc.) may actually increase costs of ownership. It may be prudent to modify such requirements. Finally, TCO represents a method for the purchasing function to support the firm's overall continuous improvement efforts by broadening the perspective of purchasing personnel, and improving purchasing's decision-making process. (Ellram 1993, 4-5)

Cost once a product is in use

Many firms that use a TCO approach are excellent at accounting for costs that occur prior to and during the purchase of a good or service. These firms usually have a good grasp of how much time, effort and expense is involved in adding suppliers to their systems and in placing orders. They know the value to their firm of on-time delivery, how much is costs to follow up on problems, match receiving with invoices, and even cut checks. However, once the item or service is consumed, these firms often lose track of the costs associated with the purchase. There are a number of costs that should be considered once a product is in service. Because these costs are often significant, and vary greatly by type or buy, they are handled separately. (Ellram 1993, 6)

Component parts and materials

Once a component or a material is consumed in the manufacturing process and becomes part of the end product or service, the purchasing function traditionally has become detached from further analysis. Costs associated with the failure of a component or material once in possession of the customer are rarely tracked and

communicated to the purchasing function. Yet such costs, which are frequently incurred after the product or service has left the company, should be very relevant to the supplier selection, evaluation, and retention process. Indeed, and understanding of such costs is critical in providing the best value not only to the producing firm, but also to the customer. (Ellram 1993, 6)

Capital Goods

In most cases, the price of a capital item is only a small part of the total cost of the item over its lifetime use. Production equipment is a good example. Critical costs that need to be considered in the total cost of ownership for production equipment include costs such as yield loss of production materials, maintenance costs, downtime, repair and overhead costs, and idle time costs for staff. Thus, there are many longer term cost factors beyond the initial price of the equipment. Operating capital includes items such as personal computers, cars, copy machines and similar items. Some of the costs associated with operating capital once in use include maintenance, replacement services when equipment is down, overlap between the nature of costs included in the costs once in use portion of TCO for production capital and operating capital items. (Ellram 1993, 6)

Maintenance, repair, and operating supply items (MRO)

Some of the largest cost many firms associate with MRO items are cost of failure and associated replacement costs when in use. However, MRO items tend to be the 80 percent of the items that make up only 20 percent of the monetary value of purchases. Thus, because MRO items are very transaction intensive relative to their price, in some cases a true total cost perspective may reveal that the lowest TCO comes from maintaining inventory. Consequently, a TCO approach must weigh the costs of maintaining inventory, and potential obsolescence risks, with the potential down-time and other inconvenience costs associated with not stocking and MRO item.

Some firms delegate to a third party distributor the management of their MRO items. In such cases, the buyer usually pays the third party more of their own money than if the items were purchased directly from individual MRO suppliers.

However, such a system may cost less in terms of the total cost of ownership by utilizing the distributor's expertise, volume buying leverage, and improved emergency responsiveness, and by reducing internal costs through paperwork reduction, error reduction, and lower inventories. (Ellram 1993, 6)

Services

It is usually more difficult to pinpoint costs incurred after a service has been performed because of the intangible nature of the service. Some of the issues are also intangible; for example, does the service performed meet the user's needs and leave the user feeling satisfied? More tangible issues that should be part of the TCO for services include items such as the user's need to have follow-up or rework done because of incomplete or unsatisfactory service performance, costs of service agreements, and costs of services performed outside of service agreements. (Ellram 1993, 6)

3.3 Challenges and other considerable issues with TCO

Using TCO as a part of procurement work especially in project environment is verifiably dependent on industry and on purchased items. There are several often mentioned reasons for not implementing TCO and most of them are related to company culture and deep-seated habits but also some prejudice that calculating total cost is more challenging than it is. These issues can be classified in more detail as cultural, education or training related, and resource allocation issues as shown in table 2.

Barriers to TCO implementation

Cultural issues

- Cost is not important to users
- Not invented here – syndrome

Education or training issues

- Image of inflexibility of TCO approach
- Need tools or training
- Too theoretical
- Frustration of trying to quantify soft issues
- Lack of user expertise or confidence
- Defining the scope of TCO modeling
- Identifying all relevant costs and benefits

Resource Issues

- Lack of readily accessible data to support efforts or lack of systems
- Labor intensive to develop and support
- Lack of resources to develop, implement and maintain

Table 2. Barriers to total cost of ownership implementation (Ellram, L. M. 1994, 175)

Cultural issues relate to general resistance to change, and the “not invented here”-syndrome. For some of the clients, price is everything, and they simply don’t want to hear about any extra cost. For other clients, there is little or no concern about cost or price, because they are not held accountable for outlays for items they are requesting.

Education and training issues relate to educating those in the firm, including the purchasing function, to overcome misconceptions about TCO. This includes providing them with proper tools to use and understand TCO, and to be able to identify when to use TCO and what cost factors are important. (Ellram, L. M. 1994, 175)

3.4 Challenges with total cost calculations and projects

The total cost calculation produces valuable information for comparing options and following the performance of procurement. The lead-in of calculation is often challenging and time consuming process. Balance between the benefits of total cost contemplation and needed contributions must be considered case by case based on each target. The easiest entity to control is the influence of purchasing price to direct inner costs such as the production process. The target of examination is in short term incidents and preparing evaluation is rather simple. Calculating indirect and life cycle costs is much more challenging and difficult. It is notable that total cost calculations are based on values available at the time of the analysis and do not foresee possible unexpected changes in cost levels such as crisis, social and political changes or high rise of cost level caused by fierce changes of the market.

According to Iloranta & Pajunen-Muhonen (167, 2015) it is essential that the organization is functioning in cross functional way to communicate and achieve the best information available for the purpose of total cost calculations. This requires also that the management department is involved in development work.

It is good to keep in mind that the total cost calculation doesn't have to be continuous; instead only one cross-section calculation project will bring in an adequate basis for making decisions. Many times even the systematic pondering, subjective evaluation and documenting things will guide towards total cost contemplation and bring in adequate information basis for comparing different options. (Iloranta & Pajunen-Muhonen 2015, 167-168)

When considering the challenges in project procurement there are clearly some issues that come across. Before any project is started, there is a cost estimate created and based on this a project budget is created. The project budget is setting the limits for all investments and purchasing. This can be a very limiting factor because it doesn't take life cycle costs of a purchase into account.

In general projects are directed too much according to project budget and possible budget overruns are putting pressure on purchasing by the lowest price, and that is of course the purchasing price. Therefore the project budget is often more relevant to direct procurement than TCO and life cycle costs. One challenge is obviously to be able to change the philosophy of project procurement, in a way that the concept of cost could be more of a global approach than strictly limited to certain budget of a short term.

4 FRAMEWORK FOR APPROACHING TCO AS A CONCEPTUAL TOOL

To make TCO more approachable, there is a variety of visual models to present the topic simply and visually. A logical way to view the costs of ownership is based on the order in which the cost elements are incurred, that is as they relate to transaction sequence: pre-transaction, transaction and post-transaction. Also a procurement total cost counting approach is presented as an option for transaction point of view.

4.1 Major categories for the components of total cost of ownership

One example of a simplified visual model is a framework for understanding total cost of ownership such as the one presented in table 3 which is showing the major categories for the components of total cost of ownership visually.

<p>Framework for understanding Total Cost of Ownership concept</p>
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Pre-transaction components

- Identifying need
- Investigating sources
- Qualifying sources
- Adding supplier to internal systems
- Educating
 - o Supplier in firm's operations
 - o Firm in supplier's operations

Transaction components

- Price
- Order placement/preparation
- Delivery/transportation

- Tariffs/duties
- Billing/payment
- Inspection
- Return of parts
- Follow-up and correction

Post-transaction components

- Line fallout
- Defective finished goods rejected before sale
- Field failures
- Repair/replacement in field
- Customer goodwill/reputation of firm
- Cost of repair parts
- Cost of maintenance and repairs

TOTAL COST OF OWNERSHIP

Table 3. Major categories for the components of total cost of ownership (Ellram 1993, 6-8)

Before beginning the implementation of a TCO approach, it is critical for a firm to have an understanding of its major costs of ownership. To help identify these costs, the firm can use the transaction cost framework to identify the total costs of ownership for each purchase category (components/materials, MRO, capital for production, capital for support and services) management is interested in exploring. While individual items within each category may vary slightly with respect to relevant cost elements, the development of such a flow chart as presented in table 4 can provide an insight into the potential issues affecting each category. (Ellram 1993, 6-8)

Pre-transaction costs

As indicated, pre-transaction costs are those costs that occur prior to receiving the purchased items, and even prior to placing the order. Pre-transaction costs include all costs incurred from the time that anyone within the firm begins to think about and investigate the possibility of buying an item, up to, but not including, order placement. Some of the costs that may be overlooked are the costs of investigating alternative sources, qualifying and educating suppliers regarding the firm's systems and expectations, and adapting to the systems, styles, and delivery methods of new sources of supply.

Activity	Cost Element	Cost Drivers
<u>Pre-transaction</u>		
Need for new production equipment identified	Capital requisition	Create/file documents
	Form committee to investigate	Salaries of committee members
Form design team	Team costs	
	Identifying external candidates, such as potential suppliers for early involvement	Salaries of team members Cost of identifying, contacting, and meeting with candidates

Table 4. The Pre-transaction activities

Transaction costs

Transaction cost elements are those items that are related to order placement and receipt, and include the price of the item or service, as shown in Figure 1. Included are those costs associated with actually placing an order and getting the order in to the firm or supply chain, ready for the next value-added process. As such, transaction costs are those costs associated with preparing and placing the order, following up on the order, receiving, matching receiving data to the invoice, and paying the invoice. Transaction cost elements tend to be more widely recognized than pre-transaction and post-transaction costs, because these are the costs that occur in closest time, space, and relationship with the transaction itself. Costs that are sometimes overlooked in compiling transaction costs are purchase order preparation, auditing and matching of order, receiving and paying invoices and correction of incorrect documents.

Activity	Cost Element	Cost Drivers
Transaction		
Equipment purchased	Price paid	Cost of equipment Delivery
Equipment Installation	Installing equipment	Warranty
	Shutting down other operations	Labor, moving old equipment, raw materials, destroyed in testing, extra equipment/parts needed for installation
		Finished goods shortages, labor (if paid for idle time)

Table 5. The Transaction activities

Post-transaction costs

Post-transaction costs are those costs that occur after the purchased item is owned by the firm, in the possession of the firm, its agents or customers. The actual occurrence of post-transaction costs may be soon after the order is received, or years later when the purchased item is in use or being modified, repaired or disposed of. The more distant in time a cost occurs from the transaction, the less likely it is that the cost will be recognized as explicitly related to the purchase of a certain item from a certain supplier. As previously discussed, costs in this category are the most frequently overlooked by firms. Post-transaction costs frequently overlooked include product repair in the field, routine and special maintenance costs, costs associated with replacement part scarcity and/or obsolescence, and similar issues.

Activity	Cost Element	Cost Drivers
Post-transaction		
Routine maintenance	Downtime	Labor downtime, finished goods inventory buildup and/or shortage if lengthy
	Cost of warranty/out of warranty work	Price paid for work performed
Repairs	Downtime	Labor downtime, finished goods inventory buildup and/or shortage if lengthy
	Cost of warranty/out of warranty work	Price paid for work performed

Table 6. The Post-transaction activities

These costs are often difficult to track, and may be separated from the purchase by a great deal of time. For component parts, a firm is more likely to associate post-transaction costs with a particular buy if they occur soon after the transaction. Such costs may include lie fall-out, part failure in finished goods testing, and field failure that occurs soon after the sale. For capital equipment, post-transaction costs such as equipment down-time, repair and maintenance typically are recognized as being associated with a particular piece of equipment. However, rarely does a firm that does not use a TCO approach account for those costs separately and go back and review the capital acquisition decision from a TCO perspective. These cost allocations described by Ellram do not take into consideration the cost structures inside supplier and the supply chain. When in fact the cost of the supplier and supply chain, inner costs and cost from the client and the distribution chain should all be added together to achieve the total cost. (Iloranta & Pajunen-Muhonen 2015, 154)

4.2 Procurement total cost counting

Another way to look at the total cost effects in practice is presented in chart 1. Many procurement professionals value total cost counting for its deep understanding for efficiency of the suppliers and product or service life cycle effects for the organization and for the client. Total cost counting directs to considering the costs systematically and forces to take into consideration every actual cost effects. Cost information gained from the calculation will guide towards better advised decisions and it will be a strong element in the purchase negotiations.

According to Iloranta & Pajunen-Muhonen (2015, 156) the total cost method is offering a possibility for objective and transparent comparison of the alternatives. Especially in public administration the most affordable price is generally the first criterion when making a procurement resolution. Only after a systematic total cost calculation, it is clearly justified to choose some other than the cheapest offer. This kind of thinking forces to evaluate different long term economic effects for quality based factors.

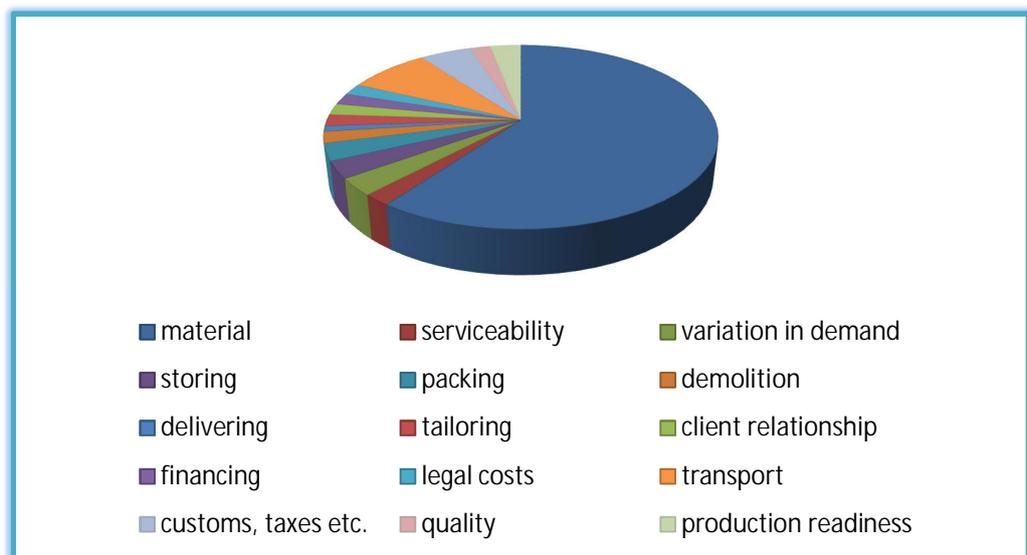


Chart 1. An example of a total cost model for procurement resolution

5 IMPLEMENTING EXAMPLE OF TCO INTO ORGANIZATION

When actually implementing Total Cost of Ownership in an organization, it takes time and effort to make arrangements and changes to be able to reach the level of operation. That requires commitment and sometimes a change in working culture, before a new method can be implanted to working routines. The concept of total cost of the supply chain from sub suppliers to final client is also in big role and the ability to outline and model suppliers cost structures. Modeling of the costs is simpler than it might seem.

5.1 Implementation issues

According to Ellram (1993, 9) The preceding discussion of the potential elements that make up the total cost ownership for a given purchase from a given supplier is by no means comprehensive in nature. The myriad of issues that may impact the TCO for an item is almost endless. Given that most firms do not have detailed cost data readily available, nor do they have systems for monitoring and tracking TCO, a simplified approach for total cost of ownership analysis is essential to make TCO workable, without becoming overwhelming.

There are several approaches an organization can take in implementing a TCO philosophy. First and foremost, the organization must move away from solely a price orientation, to grasp the idea that total cost may be much more important than the price. To experienced TCO users, this may seem like an easy task. However, for an organization that has been operating in a highly price competitive market, focusing on supplier price reduction, TCO may be a very difficult concept to sell to others within the firm. (Ellram 1993, 9-10)

The development and implementation of a TCO approach in purchasing will likely be a major undertaking for an organization for a variety of reasons. The first critical issue, as mentioned before, is that the firm must move away from a price

orientation to a TCO philosophy. Purchasing may have to demonstrate that a TCO philosophy is a superior way to manage and understand costs. The proof may have to come through a successful TCO pilot operation.

Second, few firms have accurate cost information for the pre-transaction, transaction, and post-transaction cost components. Even fewer firms have this detail data at an item level. Thus, significant effort may have to be devoted to:

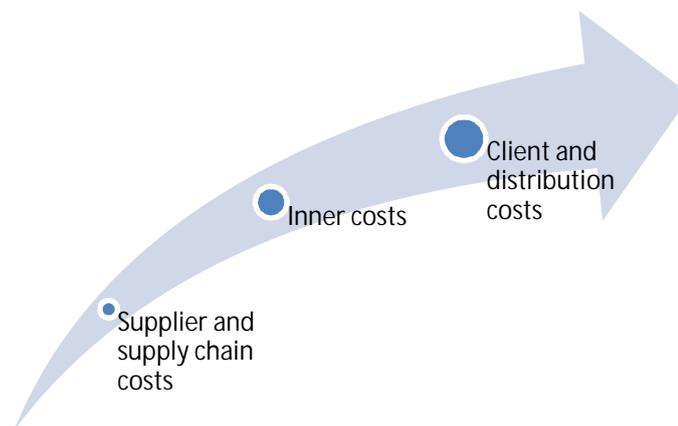
1. Develop a process flow chart to sharpen the focus on the firm's pre-transaction, transaction and post-transaction cost elements
2. Determine which cost components are significant enough to warrant tracking. There are probably a few key cost components that make up the majority of TCO expenses for a given item.
3. Determine how the significant cost components will be tracked.
4. Gather and summarize the relevant cost component data.
5. Analyze the results.

Third, the firm needs to determine where to begin its TCO efforts. It could begin with one item, a family of items, items that fit into different buying categories – such as a component, a capital equipment item and so on. This decision is very individual by firm, depending on the industry and the firm's overall and TCO philosophies.

Fourth, a firm must begin to think about how and where TCO will be used. It could be a tool reserved for critical items, or be more broadly used. TCO could also be used to select suppliers, manage costs with current suppliers, or allocate purchases among suppliers. Will one TCO model be used to provide the data to support all those efforts? The proposed scope will have an impact on the way in which a TCO approach is implemented. (Ellram 1993, 9-10)

5.2 Modeling of supplier costs

Total cost calculation often leaves out the factors behind purchasing price and concentrates more in effects to inner costs and client's costs after purchase resolution. That originates from the assumption that pricing and cost structures behind the purchasing price cannot be influenced. Modern total cost contemplation is aiming to include also suppliers cost structure to analyzing and modeling, because there is a possibility to have a strong influence in them. Ability to outline and model suppliers cost structures is one of the most essential skills of procurement professional as shown in picture 5. (Iloranta & Pajunen-Muhonen 2015, 164)



Picture 5. Total costs of the supply chain from sub suppliers to final client.

Modeling may sound very complex and difficult and it can be that when extremely multidimensional calculation models are used. Practically an Excel-sheet is adequate if it is systematically created. A salient point is to really understand the essence of the modeling case. The biggest benefit of modeling is to understand the relationships of cost structures and different cost factors. That is especially true in strategic procurement, service procurement and with complex entities procurement. Modeling stands for understanding the inner cost structure of a product or service and following questions are emphasized:

- Which cost instalments are consisted in the price or cost?
- Which factors have an influence on the size of the cost instalment?

- What kind of prerequisites do the suppliers have on economic and effective operations considering each cost instalment?
- What kind of expedients are there to influence size of the cost instalment?
- What kind of expedients does the organization have on each cost instalments?

After clearing out these questions come the following questions that will pin-point or evaluate the possible supplier candidates:

- On which geographic area is each of the cost instalments lowest and why?
- In which country or on which business lines are cases handled best and why?
- Which technology is the most efficient in executing each case?

(Iloranta & Pajunen-Muhonen 2015, 164-165)

5.3 Calculation risk factors for TCO

TCO creates value to the firm and it is more than a tool. TCO is more likely a philosophy that guides purchasing in the supplier selection decision as well as in supplier evaluation, negotiations and volume allocation among suppliers. To get started with the implementation of TCO, firms must first develop an understanding of the specific costs that are important in their firm. One way of doing this is to develop a process flow chart that tracks a purchased item through the entire supply chain – from pre-transaction (order placement) to transaction (order receipt), to post-transaction (subsequent use and disposition). This activity in itself can provide some useful, insightful information. A process flow chart can help identify the major cost elements in addition to price and provide focus and direction in developing and implementing a TCO approach. (Ellram 1993, 10)

There are also cases, when total cost calculation does not produce any added value compared to the amount of work when making the calculation, or if the forthcoming costs cannot be allocated precisely. These kind of forthcoming costs are for example semi-finished products and components that are used for producing several end products or in several ways. In these cases, the total cost calculation is not worth the effort. (Iloranta & Pajunen-Muhonen 2015, 159)

When examining the sides of TCO contemplation to procurement work in projects, there are many factors to take into consideration. First of all there are some risks that must be taken into account. It can't be known for sure how many years will the purchased item i.e. a heat exchanger last and how many times it must be serviced or adjusted during its life time and there for it can't be calculated absolutely accurately ever. TCO for a single purchased item, in this case an equipment package is simply formed of purchasing price, service and shutdowns, and possible additional costs.

Of course there could be a confidence interval created for determining the possible risks of cost and their impacts for cost assessment. However that is quite a complex issue and takes time to develop to reach reliability. Time is strongly a determining factor when defining the benefits of the TCO and it is quite obvious that TCO can't be considered purely in terms of money and costs as it is much more essential to really understand the concept of it.

The factors that will have an impact on the determining of TCO:

- Impact of equipment life time
- Availability of spare parts
- Economic stability of the supplier
- Supplier evaluation, supplier candidate evaluation
- After sales operations
- Experiences with operators and maintenance personnel

After looking at the most common TCO factors that have been compared, the TCO should at the least take into consideration the following cost factors for each equipment package:

- Price of the equipment, spare parts for 2 years and capital spares, inspection and testing, erection and supervision, commissioning and training. These will form the total cost of the equipment.
- Financing cost that is formed of the cost of instalments according to negotiated payment schedule.
- Extra and additional costs for engineering expediting, maintenance and transport which were not included in the price originally. These costs will form the hidden cost.

6 TCO IN SUPPLIER PERFORMANCE EVALUATION AND SUPPLIER SELECTION INCLUDING RISK FACTORS

At the early stage of procurement process, there are big decisions to make, such as to nominate and to decide the supplier candidates who will receive the enquiries. There are numerous suppliers that are able to bid for a certain equipment package and it depends on the client and on EPCM contractor, which finally are selected as the ones who are involved. At that point, the decision is relatively significant when considering the risk factors and impacts that the selection can have.

6.1 Supply chain risk management for supplier selection

According to Micheli et al. (167, 2009) there are several supplier selection methods used and defined, from simple scoring and matrix methods to more advanced mathematical programming approaches. All of these approaches have been proposed with the aim of taking preventive action against unforeseen events because risks cannot be completely eliminated, as it has been recognized that supplier selection helps to reduce the overall supply chain risk by reducing the supply risk. Concerning supply risk, both operational, such as uncertain price, uncertain lead time etc. and disruption risks, such as earthquakes, currency evaluations etc. have to be considered within the concept of supply risk. *Secondly*, a set of generic operational risk sources has been identified, which can be grouped into three main categories as presented in table 7.

Category	Supply risk sources
Product related	Product design changes Quality
Market related	Price increase Number of available suppliers Geographical concentration of suppliers
Supplier related	Capacity constraints Cost reduction capabilities Lead time Environmental performance Financial health Failure to meet delivery requirements Inbound transportation Information systems compatibility and sophistication Inventory management Management vision Process technological changes Volume and mix requirement changes

Table 7. Categories of Supply Risk Sources (Micheli et. al 2009, 166-177)

Thirdly due to a fact that a supply risk arises within the context of a buyer-supplier relationship, and the awareness that is possible to reduce the supply risk propensity by forming alliances and the supplier-related supply risks can originate both as relational risks and performance risks, which can be properly managed, respectively through equity and non-equity alliances. (Micheli et al. 2009, 167)

In the EPC industry, at least for the important acquisitions (i.e. critical supplies, in terms of value, quality, time etc.) non-equity alliances can be observed to be mostly used to reduce the supply risk propensity, because of two main reasons: (1)

the costs of opportunistic behavior are generally perceived to be lesser than the cost of inadequate performance (so that equity alliances are not the preferred format), and (2) the repeated change of supplier prevent early alliance from being a long-term buyer-supplier relationship, making it unprofitable to establish an equity alliance. Thus, the EPC companies mainly use the contractual arrangements to prevent both performance risks and relational risks. (Micheli et al. 2009, 167) That is true based on practical information, and alliances are necessarily not seen as an equal approach, when most of the purchasing resolutions are made emphasizing fair competition and tender comparisons, and the decisions are based more or less on purchasing price.

6.2 Supplier selection connected with supply risk and TCO

The list presented in table 5 and, the structure of the supply risks sources proposed are a very useful starting point. According to Micheli et al. (2009, 168) a generic process of risk management, the risk identification phase is only useful when followed by the identification and quantification of the possible mitigation actions to reduce risks and to exploit opportunities, so as to effectively manage supply risk. This is a key issue not only in supply risk management, but also in supplier selection. In fact, in spite of the variety of criteria and methods proposed by literature, supply risks and the possible interventions have seldom been explicitly considered in supplier selection, and this does not match with the current turbulent business environment, where risk becomes the decision driver and measure of the attainment of a proper supply performance. This is even more so in the EPC industry, where under resource constraints supplier selection is used as an alternative way to supply risk management in order to mitigate supply risk. It seems that many EPC companies do not perform an accurate supply risk management process for all of the products and services, because suppliers are previously accurately selected, so that the supply risk is preventively reduced. In more detail, the construct of both supply risk management (SRM) and supplier selection (SS) includes two dimensions: (1) the supply risk sources/supplier

selection criteria considered and (2) the level of effort which is provided to perform SRM/SS. It is plain that these two ways should not be considered as mutually exclusive alternatives. Instead, they should be both implemented and coordinated to achieve the best performance in supply risk mitigation or exploitation. (Micheli et al. 2009, 168)

All these concerns make the relevance of the total cost of ownership approach to supplier selection come to the surface. Even in a complicated monetary-based shape, the output of the TCO approach is a single value, which is deemed of high practicality when making decisions, and this explains why TCO is often used by the buyers in the EPC industry. Nevertheless, according to Micheli et al. (2009, 169) it has been highlighted that the few approaches of optimization under uncertainty are typically prescriptive, TCO included. After a decision about the approach to be used, a final solution is immediately given, without any further intervention of the decision maker. This kind of approaches should be substituted by something different, trying to preserve the information for the decision maker to make their best decision. TCO allows identifying the main areas of improvement, which is useful to negotiate and to enhance the buyer-supplier trust, and to gather structured information for subsequent supply risk management. Nevertheless, as mentioned before risk identification phase is only useful when followed by the identification and quantification of the possible interventions to effectively manage supply risk. Micheli et al. (2009, 169)

Supplier selection can be taken into account in early phases of procurement, already in pre-design phases when making the cost estimate. If at that point there is a supplier register available, it can be used to screen the candidates and based on their preliminary information and budgetary tenders, there can be a classification created to help the coming phases. It would be most beneficial to get as much cost information as possible at the earliest stage to make supplier selection more eloquent in the design phase and also for the accuracy of the cost estimate.

7 COST ACCOUNTING LINKAGE TO TCO

The first thought that comes into mind when talking about any cost based method, is savings, efficiency in cost management and controlling of assets. Even though TCO contemplation is more than just about saving money, it is unquestionably connected to that and there is no way to go around it. The basics of the cost classifications and the profitability idea must be understood as well with especially the term Net Present Value connected to the TCO concept. The term Life Cycle Cost (LCC) is often paralleled to TCO and it can be understood in the same way. The basic idea is to look at the life cycle of equipment or item and define the costs and impacts. This chapter is explaining what life cycle cost analysis is and what kind of factors must be considered when making an analysis and where the results can later be utilized.

7.1 Cost classifications and models

The basis for a traditional cost accounting is to divide total costs as shown in Table 1.

Separate Costs	Variable Costs	Direct Costs
Joint Costs	Fixed Costs	Indirect Costs

Total Costs

Table 8. Classification of costs

The most common way is to split the costs in variable and fixed costs. The level of output defines whether cost is variable or fixed. Level of output is quantity of goods or services produced in a given time period. Variable costs vary with output such as salaries, utilities, materials used in production etc. Fixed costs are independent of output such as rent, buildings, machinery etc.

Fixed and variable costs are divided in direct and indirect costs for accounting. A direct cost is the cost of producing goods or services, and they are only reported when the goods are sold. These costs can be connected to sales of a single product. An indirect cost is an overhead that remains about the same whether there is sales or not such as rent. These costs often serve several products or services. Joint costs are not depended whether the project is implemented or not. Separate costs are the costs that will not happen if the project is not implemented, such as product, project, and client event costs. (Puolamäki 2007, 63–65)

Other terms that are relatively often used when talking about TCO is OPEX (Operational Expenditures) and CAPEX (Capital Expenditures) costs. CAPEX stands for capital costs such as investment costs and depreciation costs, whereas OPEX is operational costs. CAPEX/OPEX -costs came across especially when interviewing mining persons involved with mining industry procurement and costs. So when comparing the meaning of the classifications, these costs can be paralleled to fixed cost and variable cost presented earlier in table 1.

7.2 Profit of the investment and Net Present Value

Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflow over a period of time. NPV is used in capital budgeting and investment planning to analyze the profitability of a projected investment or project. The following formula is used to calculate NPV:

$$NPV = \sum_{t=0}^n \left(\frac{R_t}{(1+i)^t} \right)$$

In this equation:

R_t = net cash inflow-outflows during a single period t

i = discount rate or return that could be earned in alternative investments

t = number of time periods

NPV = (Today's value of the expected cash flows) – (Today's value of invested cash)

Equation 1. Net Present Value calculation (Net Present Value 2018)

A positive net present value indicates that the projected earnings generated by a project or investment (in present value) exceed the anticipated costs (also in present value). It is assumed that an investment with a positive NPV will be profitable, and an investment with a negative NPV will result in a net loss. This concept is the basis for Net Present Value Rule, which dictates that only investments with positive NPV values should be considered. (Net Present Value 2018)

To make profitability analyses the profit of the investment is calculated by defining the NPV today and for say 25 years ahead and calculated with discounting interest, and if that results as a positive value, the investment is profitable.

7.3 Life Cycle Costs (LCC) and LCC analysis

Life cycle costs are all costs combined that are formed or are expected to be formed during the item's life cycle. Life cycle is starting from the definition phase of the equipment or system and ending when it is finally withdrawn from use, demolished or alternatively recycled. There can be various different costs during the life cycle such as during designing, manufacturing, use, training, maintenance and final demolition. Most of the costs are originated during use and unavailability. Especially in continuous process industry the unavailability costs for shut-downs can be significant part of the life cycle costs. These costs caused by shut-downs can be straight reduced from the company profit.

When comparing different options for design, the LCC analysis is directing decision towards the best entity which will achieve the lowest TCO during an

items life cycle. New possibilities for equipment and process solutions can originate based on the results of the analysis. The analysis will presumably guide procurement resolutions based on life cycle of the equipment rather than the investment cost. Challenges to the analysis are caused by future estimations where costs and other factors are variable. Estimations should be made according to best knowledge and leave space for assumptions in that way that the analysis is not based only on examining investment costs. It is anyway true with most of the equipment, that the investment cost is just a fraction of the whole life cycle cost. Results of the analysis will change the information into a form that is understandable for personnel in charge of procurement and economy.

When comparing life cycle costs from different design solutions, it must be considered that most of the forthcoming costs will be based on design solutions made in the beginning of the life cycle. Most of the life cycle costs for an item are developed after start-up. In practice this means that good design and life cycle analysis at the early stage can diminish costs during its operation time. Life cycle costs can be examined from different point of view depending on the business environment. For example with long life cycle items, the life cycle costs are one of the most important factors when making the procurement resolution, whereas items with a shorter economic life cycle can be evaluated based on their repayment period. LCC analysis would be most fertile to execute for long life cycle items that have the operational costs expected to exceed investment cost multiply.

Depending on the business line, there can develop cost elements that are very different and unequal during equipment life cycle. Where shut-down costs can be relatively big for one item, great annual energy costs for other item are the most significant. The most common cost elements are listed below:

- Investment costs, initial purchase price
- Installation and order costs (including training)
- Operational costs (for operative personnel)

- Energy costs
- Maintenance and service costs (regular and derivative)
- Costs during shut-down (lost production)
- Environment costs
- Depreciation / demolition costs

LCC analysis is a valuable approach for evaluating and comparing different purchases in terms of initial cost increases against operational cost benefits with a long-term perspective. The key incentive for applying an LCC analysis is to increase the possibility of cost reductions for the operational phase, even if an additional increase in the initial investment is necessary. By applying an LCC perspective in the early design phase, decision makers are able to obtain a deeper understanding of costs during the life cycle for different design strategies. LCC analysis is defined as a technique which enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors, both in terms of initial costs and future operational costs. (Ristimäki et al. 2013, 169)

According to Barringer & Weber LCC follows a process (Figure 2.) and it includes every cost that is appropriate and appropriateness changes with each specific case which is tailored to fit the situation.

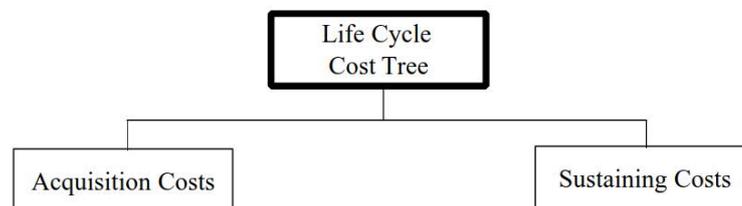


Figure 2: Top Levels of LCC Tree (Barringer & Weber 1996, 16)

Acquisition and sustaining cost are not mutually exclusive. Acquisition and sustaining cost are found by gathering the correct inputs, building the input database, evaluating the LCC and conducting sensitivity analysis to identify cost

drivers. Frequently the cost of sustaining equipment is 2 to 20 times the acquisition cost. When considering for example a simple pump – the power cost for driving the pump during its life time is many times larger than the acquisition cost of the pump. It can be deliberated whether pumps are bought with an emphasis on energy efficient drivers and energy efficient rotating parts – or maybe based on the cheapest purchase price. Each branch of the acquisition cost tree and sustaining cost tree also has other branches as seen in Figure 3 and 4.

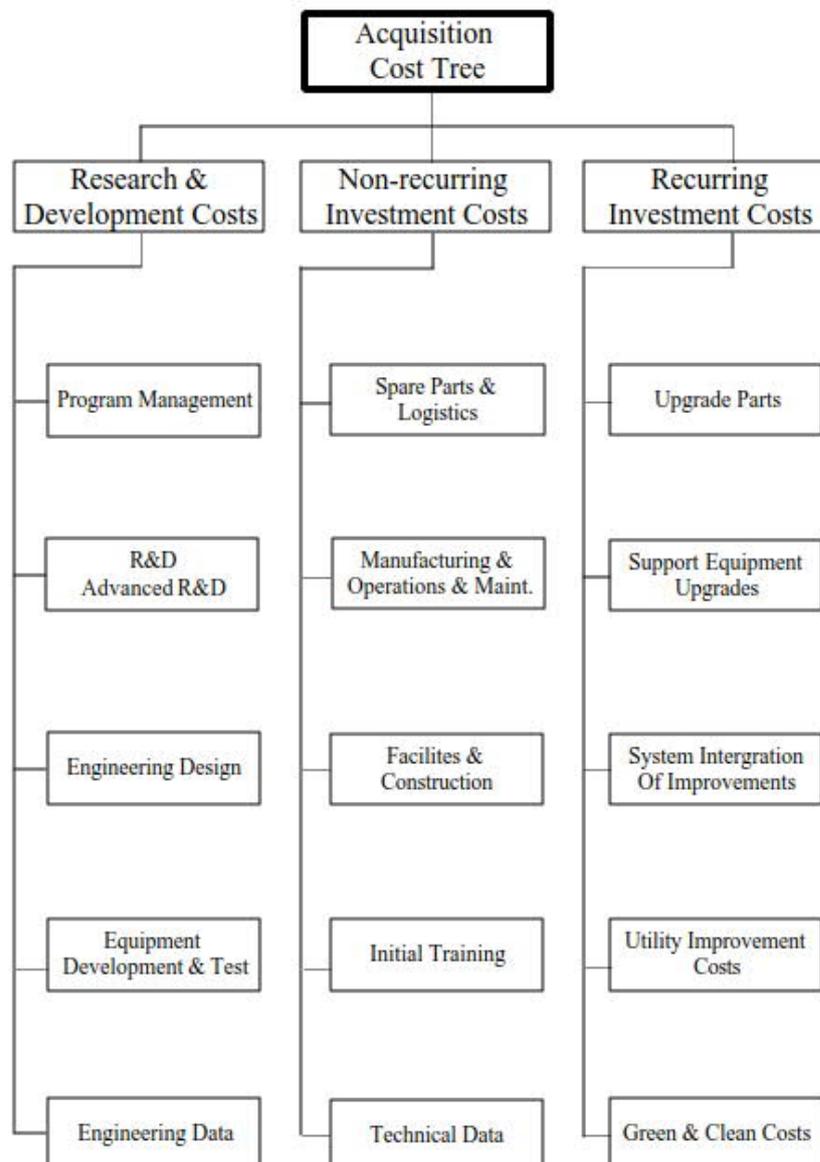


Figure 3. Acquisition Cost Tree. (Barringer & Weber 1996, 18)

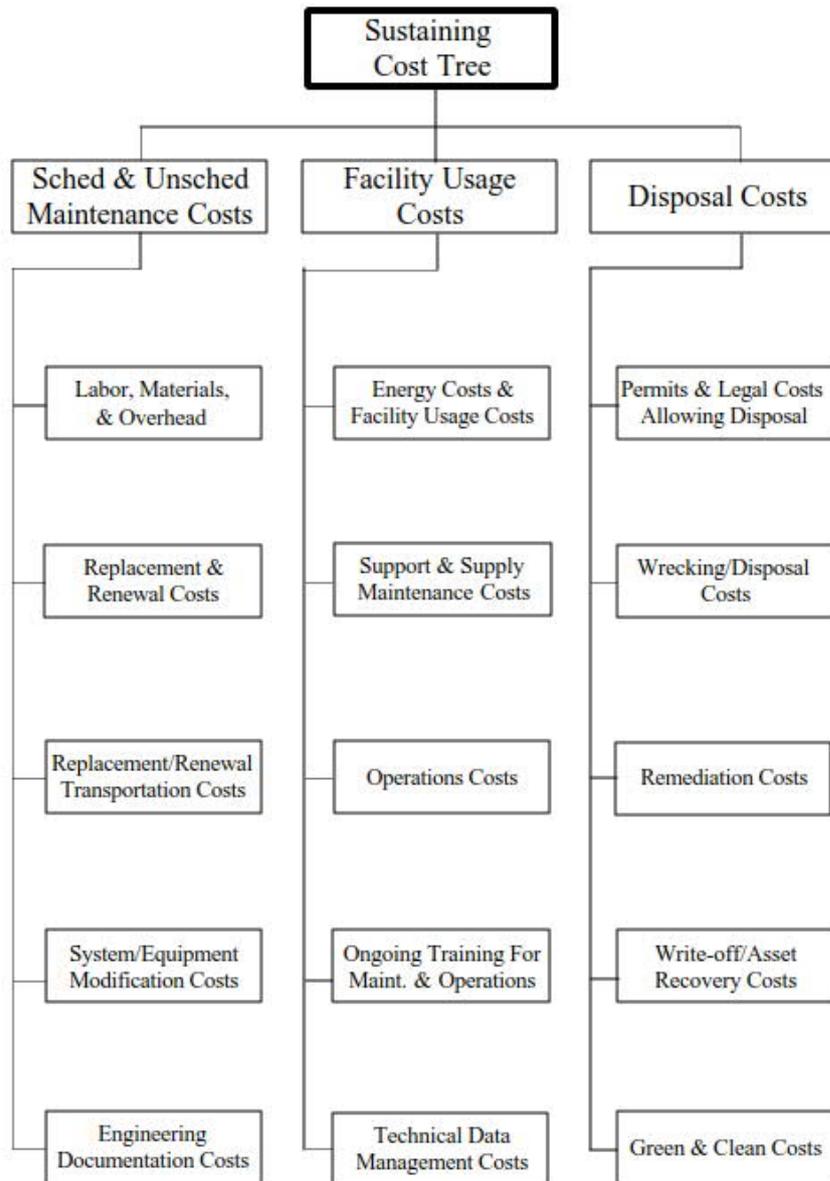


Figure 4.Sustaining Cost Tree. (Barringer & Weber 1996, 19)

The traditional LCC methodology is purely economical and does not take into account environmental aspects. A LCC analysis is based on the estimation and valuation of uncertain future events and outcomes; hence, subjective factors are involved in the process and will affect the results (Ristimäki et al. 2013, 170). Good alternatives for LCC require creative ideas. Lower LCC are obtained when creative efforts are employed in the design area, making changes downstream in the operating plants has smaller chances for improvements because it's employed too late in the improvement cycle. Design engineers are the most important link in

devising cost effective plants and naturally they have a lot of responsibility. Design engineers can't perform an effective analysis unless they have reasonable failure data from operations. LCC is simply a way, a stop on the never ending ambition for reducing costs. It is clearly not a destination but it provides the tools to engineer maintenance budgets and costs. (Barringer & Weber 1995, 53)

Although LCC is not recognized as theoretically accurate, the LCC methodology presents many benefits. For example, the analysis provided an indication of what strategic options and aspects to seriously consider, the results of the LCC analysis are presented with a common unit (currency), an LCC analysis processes and simplifies a huge amount of information and provides a valuable life cycle perspective to the different alternative options. From a user and consumer perspective, it is valuable to link environmental issues with financial outcomes in a strategic decision making context. However, it is important to note that the LCC methodology is developed only for financial analysis. (Ristimäki et. al 2013, 169-170)

7.4 Cost awareness in implementing of the TCO

In a project, any cost is strictly framed to be inside a project budget. The budget part that consists of the procurement of equipment packages can be very limited in terms of what is included and not. In most cases the convention is to include only the investment price (CAPEX) inside the budget, leaving operational costs and the whole concept of TCO outside. This is where the change should be happening. When TCO is implemented to procurement in project phase as it deserves to be, it must be included and emphasized properly. During the first pre-feasibility study phase it would be most beneficial to make a preliminary TCO analysis of the life cycle costs at least for the main equipment based on budgetary tenders. That would help the coming design phases timewise and also give the client better information of the total profitability of the coming investment. At that point it's in order to calculate NPV also for the equipment investment and compare profitability for different suppliers and what results as the Internal Rate of Return (IRR) for the investment.

8 PROJECT PROCUREMENT WORK AND TCO IN THE CASE COMPANY TODAY, METHODS USED FOR THE STUDY PROJECT AND THE RESULTS OF THE STUDY PROJECT

Current status at the moment in project procurement and current use of TCO was studied by interviewing Case Company's procurement managers, key account managers and technology managers. There are some differences between the departments or industries which are included in this study: pulp and paper industry, chemicals and bio refining industry and mining industry. All business lines have also a slightly different approach when it comes to procurement of equipment packages. The study was executed by using questionnaires (appendix 1 and 2) and interviews based on them. The results of the literature study and the responses from the interviews and questionnaires were collected and adapted to the project procurement framework presented in the next chapter.

8.1 Present state of TCO and Life Cycle Cost contemplations in the Case Company

There were altogether five internal interviews at the Case Company held during October and November 2018 with procurement managers, key account manager and technology managers before the actual interview rounds. The discussion was kept very informal and ideas that were originated were captured and plenty of notes were taken. Questions to be presented to the clients and to the suppliers were developed in collaboration and also the client contact details were given. There were about 18 persons that were contacted and half of them were able to give responses. There were some cases also where the recipients felt that they were not the right contact persons to give response. After all there was still a good cross-section of the industry studied.

Procurement for the pulp and paper industry is concentrated on big equipment deliveries for the main equipment, there are not that many competitive suppliers and the suppliers and their equipment are well known among the clients and Case Company's project persons. The main equipment consists of many items such as evaporation plant or bleaching unit. As the packages are complex and include many smaller units and equipment, the delivery is including also a lot of technology and design. Packages are sometimes multidimensional and supplier is giving them performance guarantee and has the license for functionality of single units or even the whole system. That means that purchasing value itself is high and when making tender comparisons, the information is versatile. TCO is usually taken into account in form of energy and electricity consumption, spare parts and maintenance interval. When comparing the situation between the three industries (chemicals, pulp and paper and mining) there are certain differences in how much of the ideology of total costs is already assimilated to practice. Pulp and paper industry is the first industry there was in the history of the Case Company, and the clients are familiar over decades. It is only natural that there has been development for multiple and versatile tools and procedures for working during the past. One of these is definitely the concept of requirements for availability which is considering rather progressively the life cycle costs during the plant life cycle. The typical list of requirements for availability, technical lifetime and maintenance used in the enquiry phase of a project is presented in table 9.

Life-cycle planned maintenance

This includes life cycle extensive plan for maintenance such as necessary service intervals, component replacements, big service breaks, malfunction mechanisms and condition monitoring plan.

Life-cycle spare parts plan

This includes life cycle extensive plan for spare parts such as which spare parts and components must be available at all times, which spare parts are purchased based on condition monitoring and regular maintenance program, alternatives for storing and delivery.

Design criteria and dimensioning of equipment

This includes defining the life cycle of the equipment based on how many tons of pulp, cubic meters of woodchips and operating hours it handles and what kind of load the equipment has.

Availability of a production line

This means defining the usability % of the plant, reasons for unavailability (service, cleaning, blocks etc.), and service shut-downs per year.

Follow-up of lifetime load factor of equipment

This means defining which loads are followed and what are the impacts of exceptional load circumstances to malfunction and remaining life cycle (analysis and conclusions), impact on service program, impact on condition monitoring

Maintenance time and costs

This means specifying the price for maintenance time and costs required for technical guarantee period (2 years) and beyond it (from 3 up to 10 years).

Table 9. Requirements for availability, technical lifetime and maintenance used in the Case Company for pulp industry procurement (Document used in Case Company for projects)

This above presented list of requirements has been used especially in projects where the plant is located for example in South America, and the whole maintenance organization is supposed to be outsourced, in addition there might not be information available of competent suppliers for service.

Procurement in chemical and bio refining industry is different from the pulp and paper industry as the equipment packages are often smaller and there are more units which are consisting mainly of one equipment type, such as pumps, heat exchangers or tanks. These equipment packages are not that complex and not that high in investment price compared to pulp and paper industry packages but the total budget for the equipment deliveries can still be valuable. These equipment packages are compared just as the bigger ones except the templates are very different so that not that many features are included in the comparison. For example when considering TCO, there are comparison rows for spare parts for start-up and for two years use as a standard, but often that is all. TCO costs are often understood as only the operational costs of equipment, and not necessarily covering for whole life time.

Procurement in mining industry is again different from the other industries. Equipment packages are variable in sizes and purchasing value. Big packages often consist of grinders, mills and furnaces, where the initial price is big and also the operational costs are significant in the plant budget. That is why these costs are defined in the early phase of procurement decision already. Utilities such as energy and water consumption have an impact on the total price and the product life cycle is always proportioned to the mine life cycle and the whole profitability of the mine is basically calculated based on operational costs. Smaller equipment packages such as pumps are again leaning more on the initial purchasing price and the operation costs are not taken into consideration that much. In mining industry the terms CAPEX and OPEX are used instead of TCO, which is covering the investment costs and operational costs.

8.2 The interviews

The purpose of the interviews was to get a clear picture of the current state of TCO in procurement in projects where Case Company is acting. At first the Case Company's responsible persons such as procurement managers and technology managers were interviewed in order to hear experiences of using TCO in projects, and also prior to interviewing clients and considering the right contact persons. Case Company's professionals also helped developing good and informative questions for the questionnaires (appendix 1 and 2) that were then sent to the clients. Clients were selected from all three business lines, representing pulp and paper industry, chemicals and bio refining industry and mining industry, all of these industries are under Case Company's Industry Business Group (IBG).

Questions were created keeping in view that the current state of the TCO and life cycle cost concept would be examined and compared between the industry business lines, but also to learn and develop the Case Company's procedures in future.

Clients are the main focus when receiving valuable information of TCO and needs for TCO use in future projects. It was already known that clients have many ways to handle the term TCO, not necessarily using that term but some other equivalent term such as life cycle cost, OPEX cost etc. Total costs are well known in theory but the reality is that they are not always calculated or defined, especially in the project phase.

Request for an interview and the questionnaires were sent to 4-6 persons per industry (pulp- and paper, mining and metals and chemicals and bio refining). All together the response rate was about 50%. Reasons for a reasonably low response rate were common hurry and ongoing projects that were keeping people very busy at the end of the year. However the ones that had time to answer and organize 15 minutes for an interview were very supportive and found the thesis topic interesting and necessary, and were happy to share their experiences and ideas for the development of TCO contemplation in the future.

8.3 The questionnaires

There were two different kinds of questionnaires used for the study which were sent to recipients based on their position in procurement. One form (appendix 1) was sent to the end clients of the industry and to the specialists working for the industry that were in the position where they are making decisions of purchased items. They are the ones who have set the requirements for the equipment packages or are doing that for the client as a consultant or other external party. The purpose of this questionnaire was to receive experiences of the TCO today and on the other hand to discover what is the significance of the TCO to the client and from what perspective they are looking at it. Important part of the questionnaire was also to get good ideas from the clients for the work at the Case Company for future, to be able to create the framework and to find better ways to serve them as an EPCM-contractor.

The other questionnaire form (appendix 2) was sent to the suppliers of the equipment packages. The questions were handling mostly the sales of the equipment and the factors that have an impact on the price and how the life cycle costs are being involved in the pricing and sales phase of the equipment. It was also asked whether the clients are interested in knowing the total costs and how much is it valued compared to the investment price. One point behind the questions was also to find out how the suppliers value the life cycle of the equipment, covering the design phase, sales phase, operation phase and finally the end, which means disposal or possibly recycling the equipment materials.

8.4 The results of the questionnaires and interviews

When looking at the answers given to questionnaires there are many similar answers that are repeated throughout the recipients regardless of the industry and also there are differences that confirm the assumptions of industrial behavior as it can be observed from table 10 and table 11.

Question 1: How do you define TCO in project procurement?

- *Basis for TCO is not only unit price/hourly price but in added value of the equipment. Total cost consists of price of equipment, own work, service, life cycle, safety (hidden cost). Hidden costs are developed after the equipment is commissioned and used; these costs are typically related to safety or maintenance. (Specialist of Pulp and Paper Industry)*
- *Depends on the importance of the equipment and the cost of operation that function. For example, transformer – efficiency of voltage energy, life cycle can be 25 years, running time is 24 h/day. Energy loose must be taken into consideration. (Client of Chemical Industry)*
- *Distance has significance, 300 km or 10 km, every time cost or accommodation costs. (Client of Chemical Industry)*
- *CAPEX and OPEX costs are used generally as the terms in mining industry. OPEX costs define then the TCO costs. CAPEX investment + yearly OPEX (variable + non variable costs), these are input to the financial model. (Specialist of Mining Industry)*
- *Contemplation should be demarcated to costs over 10 years of time. Planned and special maintenance works estimated for hours / year, there is no idea to use price information for work, as it will most probably change over the time. Spare parts and supplies estimated according to price level of the year of agreement. Contemplation should be examined by departments as different suppliers have different process and equipment. (Client of Pulp and Paper Industry)*

Question 2: Do you participate in defining TCO for equipment packages? If yes, describe how?

- *For example in big investments there is an estimate or a service program required for 10 years of time and that way the life cycle costs are taken into consideration. There can be a part of the process which has a low investment cost, but then chemicals or wearing parts are pricey over time. TCO must be considered always at least for maintenance and service. (Specialist of Pulp and Paper Industry)*
- *Costs are defined for big equipment and unities such as grinders and furnaces. An Excel-sheet is used for comparing the costs and the life cycle of equipment is calculated based on mine life cycle, which can be for example 35 years. TCO is basically calculated for the mine depending on the ore deposit and then decided whether the mine is profitable to establish. Costs that are calculated for the equipment for its calculated life cycle (like 25 years) are service costs, currency costs, repayment period costs, interests etc. There is however a difference between the repayment periods cost and the mine life cycle cost. When the total mine investment is calculated, maintenance costs are defined as a separate cost class for the plant. (Specialist of Mining Industry)*
- *Yes, in category management and as much as possible. Trying to go close to cost of operations, and in commissioning. Standard maintenance is included, defining the scope carefully already in the Request for Information. Equipment supplier, design etc. the whole concept is taken into consideration. (Client of Chemical Industry)*

Question 3: How do you see purchasing price of the equipment and project budget related to TCO of the equipment? Is TCO cost already included in the budgeted price?

- *Purchasing price is always lower than the TCO cost. TCO cost is not usually included unless requested separately by the client. There is always a budget that is used for defining the costs, and these are the investment costs. When the project proceeds, there will always be extra costs and when this becomes a challenge, a common way is to hide these costs to operational costs budget outside the project. This can happen also the other way around, when there is a big and long project; some operational costs can also be hidden to project budget. (Specialist of Pulp and Paper Industry)*
- *Budget is usually very strict for equipment packages and decisions are made mostly based on CAPEX cost (investment cost). TCO is not included in the price, especially with smaller items such as pumps. In the bigger investments, Net Present Value (NPV) is taken into account. (Specialist of Mining Industry)*
- *No budget is including investment and the whole maintenance. In different areas, there must be calculations made for the TCO. Cash flows and costs must be considered in total. (Client of Chemical Industry)*

Question 4: What is the significance of the initial equipment price to decision making in procurement?

- *Many times equipment price is the main driving force when making decisions. Fixed project budget is not usually giving any room for long term cost forecast. (Specialist of Pulp and Paper Industry)*
- *Investment price means one time cost in the project budget. It has a big influence in the decision making. For example, a company who has cheaper investment cost, might have big chance to be selected in the project. But sometimes if you compare TCO but not only the investment*

<p><i>price, the decision might be different. (Client of Chemical Industry)</i></p> <ul style="list-style-type: none"> - <i>Common way of thinking is definitely emphasizing CAPEX cost over OPEX costs. There is still competition for the equipment packages, about 4-10 supplier candidates for smaller packages and at least three for the bigger. There would be more differences if they were searched instead of looking at the investment cost only. However OPEX costs are usually not compared. (Specialist of Mining Industry)</i> - <i>There is no clear answer, should have a certain price for investment and then all kinds of prices for the total cost perspective, for example for a 1M€ equipment. It depends on many elements. For smaller items such as pumps, it is much easier. (Client of Chemical Industry)</i>
<p>Question 5: Name the three most important matters that need to be taken into consideration in TCO of equipment.</p>
<ul style="list-style-type: none"> - <i>Service, life cycle, operational reliability.</i> - <i>One time procurement including logistics, start-up commissioning</i> - <i>Change of company culture.</i> - <i>Agree upon what is included and what is not, in calculation already</i> - <i>TCO, net present value, define the life time of 25 years for example</i> - <i>Take into consideration where are you working, when for example in Brazil, there are import costs, it's always different if you are working in other parts of the world</i> - <i>Go as broad as possible with the concept</i>

Table 10. Summary of the responses for the questionnaire from clients and procurement specialists

Question 1: How do you define TCO in procurement?

- *For example with pumps we will estimate wet end parts wear rate (life time) with costs of spares. Also pump energy consumption will be calculated with some effect of wear to the efficiency.*
- *TCO comes across mostly with big equipment, rather than the smaller ones, in any case less than 5 times / year. Especially with grinders more than with pumps. If the client doesn't require, it won't be done. Suppliers and tenders are in some cases rated by technical characters such as pitch line velocity or efficiency and price. Operational costs are mainly the spare parts costs for two years. For some special pumps such as in grinding contour there is a 5 year usability comparison made.*
- *Life cycle costs and LCC analysis, total costs and their analysis. Investment costs are defined in an optimization and filled with clients expectations for quality, performance, guarantee etc. combined with own expectations based on experience of quality, certain materials, tolerance and design to achieve the best standards*

Question 2: Do you participate in defining TCO for the products? Do customers require knowing TCO costs such as energy consumption, waste control possibilities or environmental aspects?

- *Requirements from the client are taken into account already in the sales phase of the product, for example how much material and other hardware is needed. It is also defined where the parts and equipment are purchased and the equipment package is priced according to existing price lists or before defined definitions and prices. Then the total price is formed, including margin etc.*
- *Investment cost, guarantee and performance requirements set the requirements for suppliers. Also energy consumption parameters are considered and the biggest energy consuming items are recognized together with the client in order to create the best concept.*

- *TCO is estimated and calculated for 1 or 2 years. Normally these are needed with big project or high wear & value of equipment.*
- *These are mainly just sophisticated guesses that are based on handled material etc. Some materials are extremely erosive and wearing so it is very difficult to make an actual estimate of wearing parts.*
- *There are also geographical differences, for example in Chile there is a whole organization build just for services and maintenance, and these organizations are huge. Clients are prepared to pay more for service and rely on the supplier; also they don't have to take care of it themselves. In Finland, plants in general have competent maintenance departments that can handle standard service of the plant.*
- *At the end of life cycle, in some cases pump materials can be recycled, such as chrome when the prices are high. Worn parts are searched all the time actively from clients and at the same time new replacing equipment are offered. However this works mainly in the neighborhood of the pump foundry.*

Question 3: Are TCO costs already required in enquiry materials received from customers? If yes then what kind of requirements are there?

- *The client has a budget and a target price for the product and what the price should include. The sales phase of the product fills the requirements of the client and sets then the budget for the purchase of the equipment and a target for the price.*
- *Sometimes, for example wear life time included with spares prices. Client usually wants a certain type of motor, class IE3 is a common requirement for pumps especially in Scandinavia.*
- *The investment cost is a small part of the total costs, and still it is very often ignored. It is considered as an inevitable issue, that will eventually follow anyway, and the value is not that significant.*

- *There are also big differences between countries and cultures on how the price and investment costs are valued.*
- *Also different industries have different ways to handle price negotiations no forgetting the business ownership question; public administrated companies have very different way to value the price compared to private ownership business. Public ownership business values the investment price 100% and tender comparisons are regulated so that investment price must be the determinant in all resolutions. TCO is in other words not considered at any point.*

Question 4: How is TCO considered in sales, marketing and product development and in after sales?

- *We try to offer “the lowest possible total ownership costs” This means that the client is aware of the price level, which is high compared to the competitors, but they also value the high quality of the products. Sustainability is valued high and the long life cycle of products.*
- *If the client is putting more value to the price, then something else is figured to ensure that the client will choose these products. For example there are special side products that are marketed and sold for certain premium products, such as a belt tensioner for belt-driven pumps, which will ensure a right belt tension. As this will have impact on the efficiency, it is also a question of occupational safety, which is often used for marketing. This is a value that cannot have a price tag on it.*

Question 5: Name the three most important matters that need to be taken into consideration in TCO of equipment.

- *OE (investment) price, wear life time & spares and services availability.*
- *When the client has given good information of their requirements on time and that is transferred to the design of the product, everything goes smoothly. That information can then be again transferred to own requirements for the purchase.*
- *Collect energy consumption information for single items from the client*
- *Operational cost of a the plant, these can differ a lot*

Table 11. Summary of the responses for the questionnaire from suppliers

8.5 Comments for development of the TCO concept gathered from the respondent

“The TCO concept is just now coming into chemical industry markets. It still needs to be balanced, and have a special look for basic engineering and how to move faster to design engineering. When using EPCM contractor, they need to take into account and evaluate which is better approach.”

There are signs that the contemplation of TCO is becoming important part of procurement in chemical industry sector, and there are already differences between the clients development for acknowledging this subject.

“There should be more tools for variable design values and for CAPEX costs, plant capacity variations and dimensioning changes. Sensitivity analysis for OPEX costs. For example with pumps, there could be savings if different piping and information of pump motor output were utilized.”

This comment from a specialist in mining industry can be understood so that there are not enough suitable engineering tools or applications available for making reliable and extensive enough analyses for TCO. Also there seems to be a lot pressure in executing projects efficiently in a tight schedule which unfortunately means that there's not enough time for proper clarifications.

“Energy consumption and service expectations should be defined and gone through together with the client. Cannot go broad enough, need to make sure if engineering costs are included, because mostly they're not”

“Pre-design phases should be made with extra deliberation because it really reflects on the project success in design phase of the project. This is faced often and sometimes it even means that there is no proper pre-design phase made at all. Unfortunately cost efficient way of working means too often that not enough time, money or resources are used for implementing the design.”

In these comments from clients of chemical industry and from mining industry, there are expectations aimed to EPCM-contractors direction. Design work should be divided better so that the client is served better already in pre-design phases, already in basic engineering or cost estimate phase, where a lot can be done in terms of life cycle cost planning and keeping in mind that the following phases are coming anyway for the client. Also an important point is to keep close contact with the client and at least aspire for a common understanding and targets for the total costs of the procurement and for the project in total.

“When energy consumption, service needs and basic OPEX cost estimation is made, the work is considered done. Calculation is made the same way, and not necessarily went through with the client. The results of calculation may be used or not depending if everyone approves them. Decision might still be made based on CAPEX costs.”

In this comment from a specialist from mining industry it's obvious that it is so common to use the CAPEX value in purchasing resolutions even though the information is available for the operational costs (OPEX) but for some reason it is still ignored on seemingly light grounds.

“When making a cost estimate, it is advantageous to use information of the previous projects data and results. In design engineering phase, always use the best approved solutions.”

A client from pulp and paper industry is emphasizing the importance of the initial data of previous projects before starting a new one. There is anyway a lot of information gathered from the client during often numerous previous projects that can be used in the coming projects as well.

“In pulp and paper industry, there is high development occurred for some main equipment suppliers at least for the service operations. The ones that get most benefits of it though are the equipment suppliers, since service business is more stable than projects, at least they are more predictable.”

The cost level should be based on analyses of the level of maintenance:

- *Take advantage of data history*
- *Acknowledging load factor information for equipment behind engineering and measuring the actual load factors and comparing them against the planned level.*
- *Maintenance strategy based on criticality analysis, not just estimates. “*

The client of pulp and paper industry sees the maintenance operation business being most beneficial for the supplier. That is true to some extent, because the service organizations are often big and mighty and especially when the whole

business is outsourced, there can undoubtedly be good profit for the service achieved. Service packages are tailored but still consist mainly of the same features that are easy to sell to plant organizations.

Other thing is the idea of the level of maintenance, which brings out the term criticality analysis that is the basis for a maintenance strategy which is very interesting. It means condensed that the equipment that are in within the scope of maintenance programs are grouped by their ability and probability to failure and they are then classified accordingly to low, medium or critical equipment and after that there is a maintenance strategy created for all classes of equipment.

“Requirements for availability, technical lifetime and maintenance-document or a corresponding request for life cycle costs should be included in all major enquiries.”

The document referred in this comment has been used in previous projects in the Case Company, but as mentioned before in chapter 8.1, it was mainly used in projects where the plant was located in South America, and the whole maintenance organization was outsourced. The document is still very feasible today and with some adjustments according to project or equipment, it could be used in future as a part of all enquiry material regardless of the industry or the client.

9 RECOMMENDATIONS FOR IMPLEMENTATION OF THE TCO AND THE FRAMEWORK BASED ON THE STUDY

The TCO should be taken into the project already in the pre-feasibility study phase, when the first cost and profitability estimate is made. If at that point there was enough information available of the price differences between suppliers and equipment packages, it would be very useful for the following project phases. That presumes of course that the concept of the equipment package is well defined already and there are no design changes expected that would again change plans.

One of the most important things is to have an open discussion both with the client and the supplier in order to be sure to receive all that information that is needed for a proper analysis of the TCO or LCC. In an ideal world they had a discussion before the actual bidding process had begun and would have the information already available once they receive request for a budgetary tender. The suppliers have stated that it would make their work a lot easier if they received information well on time from the client so that they could properly be prepared for the tender. The clients have given signals that they would appreciate if the EPCM-contractor would emphasize more to the basic engineering phase in order to make better preparations for the design phase of the project. If the TCO concept was included in the early phase, that would be beneficial both for the client and supplier.

Developing a tool for estimating of the TCO is very important part of the development for the Case Company's future as a serving party. That tool should include the most important factors of TCO and it should be as generic as possible so that it could be adapted to all procurement, not just to the big package deliveries where it's already being at some level noted. That tool should be a part of every tender comparison, include the definable operational costs and take also into account the life cycle of the product.

The role of the EPCM-contractor is to provide support and information to the client and produce high quality material and documents to back up recommendations which are based on experience and expertise. That requires good calculation programs and reliable analysis and results. If that information was provided to the client as early in the project as possible, leaving enough time to make the procurement resolution with confidence, there would be a lot of time and money saved from both the client and the EPCM-contractor.

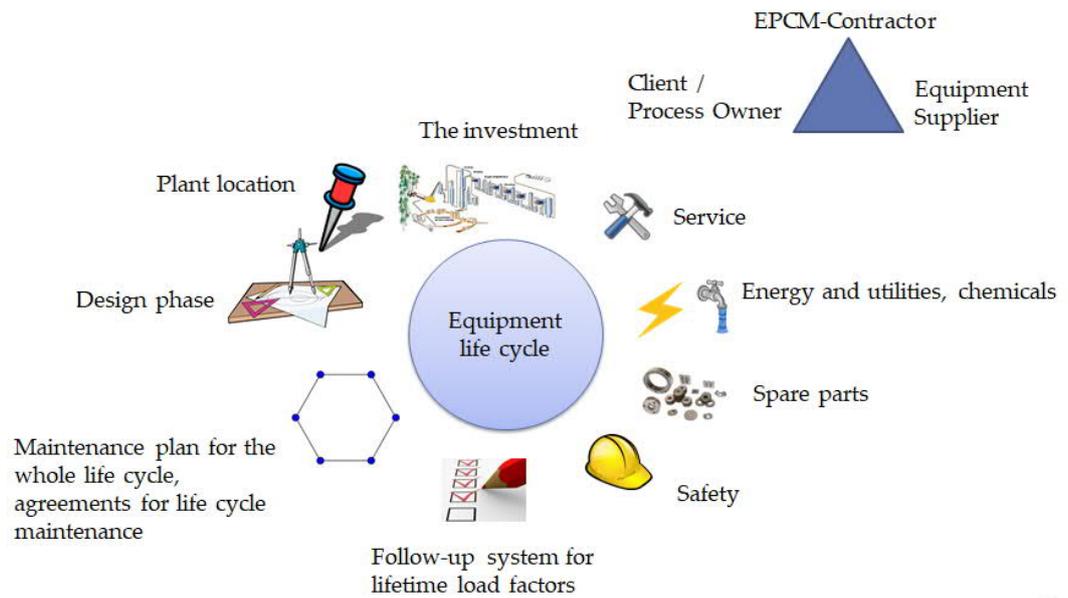
9.1 Main things in the development of the framework

Based on the interviews and answers, there are many points that are pointed out as important issues, and the concept of TCO is valued high among the clients and the suppliers. It was also positive to notice that suppliers are very willing to cooperate together with the client in order to make a better understanding of the TCO and life cycle contemplation of the products.

In Picture 6 there is a visual presentation of a life cycle of equipment inside an investment project, which is managed by an EPCM-contractor in close contact with the client and the equipment supplier, where all parties bring their own input to the contemplation. The main aspects remain the same regardless of the industry or the equipment type. There are differences in size and extent of the equipment packages or deliveries but the principle behind the concept remains the same. The responsibilities of the parties are presented in table 12.

	Client	EPCM-Contractor	Supplier	
		Project management		
	The investment		Service	
	Energy, utilities, chemicals	Design phase	Equipment data	
	Plant location			
	Follow-up system	Follow-up system	Spare parts	
		Maintenance plan	Maintenance plan	
	Safety	Safety	Safety	

Table 12. Responsibilities of the project parties in TCO contemplation



Picture 6. Headlines of the TCO in procurement for an EPCM investment project

The first steps to making a successful definition of TCO for the products and equipment packages are starting already at the design phase of the plant and there comes along the role of an EPCM contractor as well. It was emphasized a lot that already in the basic engineering phase of a plant, there should be taken into consideration what the realistic life cycle costs are. For that there should be evaluations and comparisons made to get a better picture of the life cycle costs by different suppliers and that information should be available already when making a cost estimate or investment plan of the plant, in order to make profitability estimates.

So when the project is starting, there should be a realistic project budget created which would ideally include the TCO already instead of being ignored or left outside the project totally. In that way, the investment price of the equipment would not make that massive role in defining the procurement resolution of the supplier and the equipment package. Price differences including the TCO of the equipment would be clearly requested from the supplier in the enquiry phase, so that when the price negotiations are ongoing, there would be all the necessary information already available in order to make a resolution based on total costs.

One big technicality was also the TCO or LCC analysis, and on what grounds is it prepared. It was many times pointed out that that the net present value (NPV) of the product should be calculated during its life cycle to make a realistic estimate of the TCO instead of sophisticated but rather vague guesses. All in all it seems that there are simply not the kinds of tools available for making TCO or LCC analysis specifically in project procurement, which would really be useful to have.

The suppliers were also putting a lot of importance on the communication between the client and the supplier already in the beginning of the project in order to create the best available technique for the client.

9.2 Framework for TCO adaptation in procurement

During the study phase and the thesis work, it was noticed in many occasions that the subject TCO is familiar as a term in the Case Company. It is acknowledged that the concept of costs during the project is not just the investment price, and still in many projects that is still the most determining factor in purchasing resolutions. The discussion has been opened now and after discussing with all of the parties involved in projects –client, EPCM-contractor and supplier – it is now clear that all of them want the same thing. That is to take the total costs in to better consideration in future. There is absolutely interest and expectations for the development work for a procedure or a tool to be used after this framework is published. The ideal thing would be if there was a development project started right away and the whole concept would get a quick start. The doubts are related to implementation of the concept, as development work, no matter how useful it is, is always secondary compared to normal project work.

In order to get to the target, where the TCO is being noted and taken into project procurement as a part of basic flow chart of process, there is a framework prepared and explained in Figure 5.

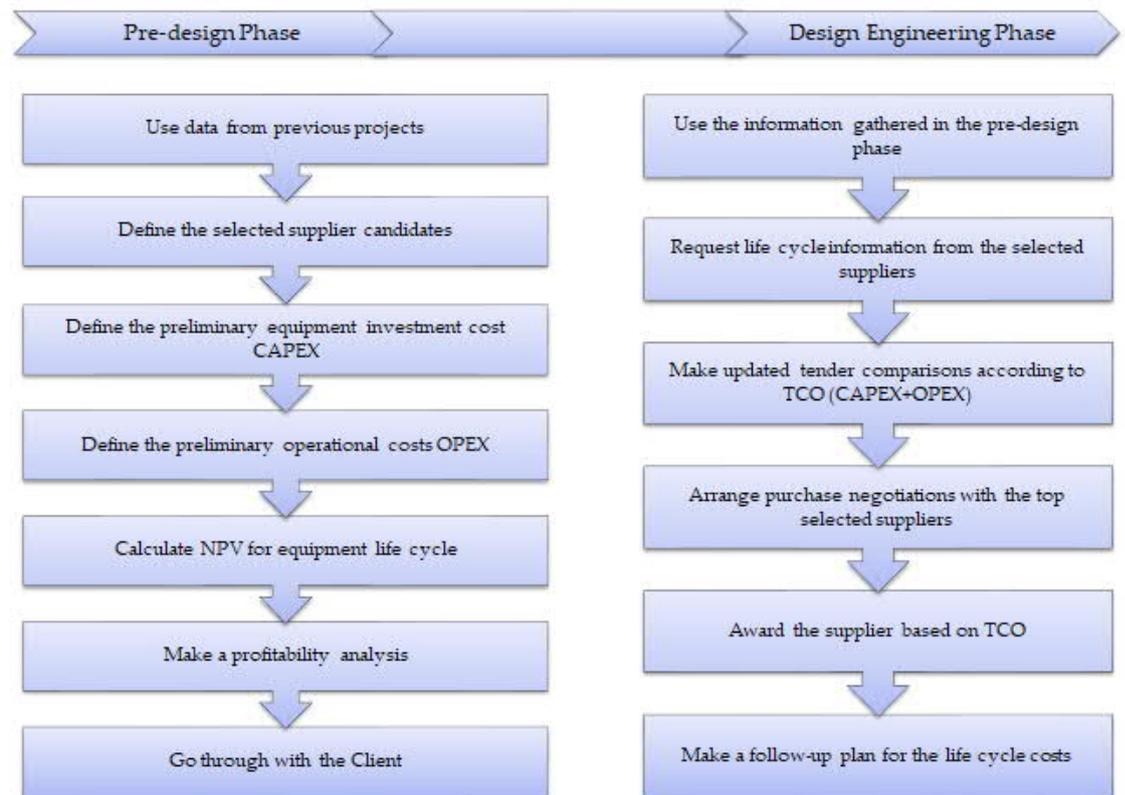


Figure 5. Framework for TCO contemplation in procurement

The steps of the framework

Pre-design phase

1. **Use data from previous projects**
Using as much as possible the information from previous projects from the same client is both beneficial and also takes the clients individual needs into account.
2. **Define the selected supplier candidates**
Make a list of selected supplier based on practical knowledge from the client and risk analysis for the supplier selection.
3. **Define the preliminary equipment investment cost CAPEX**
Prepare Requests for Tender (RFT's) for budgetary tenders and make a comparison of tenders

4. **Define the preliminary operational costs OPEX**
At the same time with the CAPEX cost comparison, take into account also the operational costs according to information received from the suppliers to the “Requirements for availability, technical lifetime and maintenance”-document or some corresponding specification attached to RFT-material.
5. **Calculate Net Present Value for equipment life cycle**
In order to make a reliable cost estimate or a pre-feasibility study of the profitability make a proper analysis based on equipment life cycle and their NPV for profitability and compare between different equipment suppliers.
6. **Make a profitability analysis**
Prepare the analysis based on realistic assumptions and make sure the TCO is included throughout the line
7. **Go through with the client**
Keep in contact with the client and update information whenever necessary so that there is a mutual understanding all the time.

Design engineering phase

1. **Use the information gathered in the pre-design phase**
When entering the design engineering phase of the project, there is an objective to have a lot of research work already made of the project and a big part of the engineering already started and therefore it will be fluent to continue forward.
2. **Request life cycle information from the selected suppliers**
At this point prepare the RFT's for firm tenders and include the “Requirements for availability, technical lifetime and maintenance”-document with possible updates in. It's not totally unparalleled to use new supplier candidates at this point if there were no suitable found in the pre-design phase as well. Information of the equipment life cycle maintenance and service needs and the consumption details must be finalized and known as well as possible for the evaluation at this point. It is very important to keep the client and the suppliers in contact all the time in order to receive the information requested on time.

3. **Make updated tender comparisons (CAPEX+OPEX)**
After the firm tender round(s), update the tender comparison for total costs of the equipment packages.
4. **Arrange purchase negotiations with the selected suppliers**
In the purchase negotiations go through in detail all the requirements for the life cycle costs and needs and make sure that all the required information is available when making the recommendation for the awarding of the supplier.
5. **Award the supplier based on TCO**
After receiving all the information and making a reliable comparison and discussing with the client, award the selected supplier.
6. **Make a follow-up plan for the life cycle costs**
Be a support between the client and the supplier in order to make a maintenance and follow-up plan for the whole life cycle of the equipment. Make sure that safety issues are being considered at all stages.

With this framework it is systematic to follow through the procurement in projects with updated rules of procedure. This framework is adjustable and is compatible with all three main industries in the Case Company.

10 SUMMARY

In order to meet the requirements of the clients, specialists and the suppliers, there should be massive changes made for the whole concept of the TCO and the whole life cycle idea. It is unfortunately common that even though the TCO is acknowledged, and can be calculated, it is still left out of the budgets and ignored from tender comparisons way too often. This is where the Case Company has a possibility to step in and hold out the helping hand to the project by sharing information and using competent ways to present the TCO concept in an understandable way for the client. When clients are convinced that the EPCM contractor can help them make the right purchasing resolution based on broad information available of the costs, they are most certainly even more satisfied with the results of the project.

The study has shown that all that information needed for the development of better tools and templates already exists. So it is really not about inventing something new and incredible as it is about adapting existing information to create better ways to do things.

Understanding the concept of TCO is not entirely about saving as much money as possible but understanding the main reasons behind it. It is only reasonable and sustainable to think deeper into the life cycle of the product and the production plants in general. In the future there will be many changes ahead, giving up of the fossil fuels for one example. There will most certainly be more importance put on sustainability and responsibility of any production and the procedures that a plant is committed to. At the same time the order of importance might turn away from money to some other values such as durable materials, sustainable design and long life time.

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APPENDIX 1/2 Questionnaire for the CLIENTS AND PROCUREMENT MANAGERS OR other PROCUREMENT RESPONSIBLE PERSONS

QUESTIONNAIRE

Please answer following questions based on your experience of the Total Cost of Ownership (TCO) in procurement of equipment packages.

Question 1

How do you define TCO in project procurement?

Question 2

Do you participate in defining TCO for equipment packages? If yes, describe how?

Question 3

How do you see purchasing price of the equipment and project budget related to TCO of the equipment? Is TCO cost already included in the budgeted price?

Question 4

What is the significance of the initial equipment price to decision making in procurement?

Question 5

Name the three most important matters that need to be taken into consideration in TCO of equipment.

APPENDIX 2 / 2 QUESTIONNAIRE for the SUPPLIERS

QUESTIONNAIRE

Please answer following questions based on your experience of the Total Cost of Ownership (TCO) in procurement of equipment packages.

Question 1

How do you define TCO in procurement?

Question 2

Do you participate in defining TCO for the products? Do customers require knowing TCO costs such as energy consumption, waste control possibilities or environmental aspects?

Question 3

Are TCO costs already required in enquiry materials received from customers? If yes then what kind of requirements are there?

Question 4

How is TCO considered in sales, marketing and product development and in after sales?

Question 5

Name the three most important matters that need to be taken into consideration in TCO of equipment.