Jani Kaljunen

IT Service Cost Accounting: A Case Study of Server Virtualization in Metropolia University of Applied Sciences

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The purpose of this study was to determine the total costs of a server virtualization service in Metropolia University of Applied Sciences (UAS). With 16 700 students and 1 000 staff members, Metropolia is the largest UAS in Finland. This study was commissioned because no thorough IT cost analysis had been conducted before, and understanding on the cost-effectiveness of UAS's IT service production was needed. Currently a vast majority of UAS's end user IT services run on virtual servers and thus server virtualization was chosen as cost object of this study.

A case study research method was utilised in this study, because it enabled an in-depth analysis of the production environment and the cost structure, a prerequisite for a valid and reliable presentation of the product cost. The qualitative data in this study included best practices and activity analysis, while quantitative data consisted of IT resource costs and usage volumes. The conceptual framework of this study consisted of a hybrid costing system, where multiple costing methods were utilized. The share of indirect data center network costs was relatively large and thus activity-based costing was used to ensure proper cost assignment. After having the knowledge of the costs associated with the current production environment, a preliminary cost benchmarking was carried out. The product cost calculation involved uncertainties due to data availability; therefore, a sensitivity analysis was performed. Finally, economies of scale associated with expansion of production volume were discussed.

The primary outcome of this study consisted of the cost of a virtual server in different scenarios, along with a presentation of the production environment cost structure. The cost level of UAS's production seemed competitive, although no final conclusion could have been made without a more detailed market study. Most of the uncertainties detected had no practical impact on the product cost. However, choices made regarding activity-based costing and cost drivers used to allocate data center network costs had a significant effect on product costs. The findings suggested that joint IT service production in higher education sector seem to be economically viable; especially, if production volumes can be increased to adequate levels.

The author recommends that the information on costs and cost-effectiveness is utilized in decisions regarding investments, budgeting, pricing and outsourcing. IT cost chargeback based on costs and resource usage should be considered. The cost of other major IT services should be determined and benefits of activity-based management considered.

Keywords	management accounting, cost accounting, activity-based costing, IT services, server virtualization

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Helsinki Metropolia University of Applied Sciences

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1 Introduction

This research is about IT service cost accounting in a higher education environment. In this thesis, the cost of server virtualization in Metropolia University of Applied Sciences is determined.

The topic of cost accounting and particularly the server virtualization service was chosen as a case study topic, because no thorough cost analysis has been conducted before and understanding on the cost-effectiveness of own IT service production was needed. Typical scenarios, where valid and reliable cost data is mandatory in order to make informed and intelligent decisions, include IT investments, IT cost chargeback, IT cost benchmarking and IT service outsourcing. The server virtualization was chosen as a case example because of its importance in IT service production. Practically all end user IT services in Metropolia run on virtual servers, with email and calendar application being the only exception.

In an article written 15 years ago, the authors describe a situation sounding very familiar. IT costs need to be controlled to remain cost effective and at the same time, IT investments are needed to maintain the competitive advantage. However, IT costs are traditionally allocated as overhead and absorbed by IT department or charged equally to business units, rather than properly charged based on actual consumption. As the authors point out, *"such indiscriminant cost-allocation schemes encourage the overutilization of underpriced services and the underutilization of overpriced services – both of which lead to suboptimal organizational performance"*. (Gerlach, Neumann, Moldauer, Argo & Frisby, 2002, 61) Similarities can also be found in a case presented by Ellis-Newman & Robinson (1998), where the decline of government funding of universities led to cost cuts and a need for more precise cost accounting and proper budgeting practices emerged.

In this research, financial and technical matters are examined solely from Metropolia's point of view. Since cost accounting methods are universal, and most, if not all, Finnish higher education institutes have similar virtualization environments in place, this thesis may be considered to be of national interest.

In addition to monetary cost of the case service, this thesis also presents cost data and an accounting model, which can be used to determine the cost of other IT services as well. The use of activity-based costing and other proper accounting techniques introduces visibility on cost level and cost structure, both of which previously had more to do with guesswork than reliable data on actual production environment.

This research is very practical in nature and focused on the case of server virtualization service. The objective is to develop a cost accounting model that can be used to reliably determine the cost of IT services, given the available data. Basic components of the development work consisted of data and accounting methods. The development process included numerous iterations, where accounting techniques were applied on pieces of cost and volume data, after which results were evaluated. In each iteration round, either the need of more data or refinement of accounting technique, or both, was discovered. This iterative process was then repeated numerous times, until satisfactory results as a whole were obtained. The accounting techniques used in this thesis are straightforward and the case service in itself relatively well defined, but as will be seen, the overall IT environment involved is rather complex, thus making the apparently simple task of cost accounting remarkably challenging.

The reliability and validity of obtained cost figures are primarily dependent on cost and volume data, and proper accounting techniques. The accounting methods are simple and the numerous calculations, although long and technical in nature, should be relatively easy to follow. In many cases, however, the accuracy of final product cost is limited by data availability. Most of the cost data is well documented and therefore reliable, and sufficient for the purposes of this research. Some of the costs are subject to estimations but as will be seen, the relative importance of these cases is limited. Especially important is volume data related to various infrastructure resources, which is needed to properly allocate cost of these resources to respective activities and services causing them. The challenges go deep into the IT infrastructure and are very much case specific. These situations lie at the heart of cost accounting, where the accountant must solve with own expertise both what accounting technique to use in a given situation and to what extent the increase in product cost accuracy by obtaining additional data is justified by the cost of doing so.

It is hoped, that this thesis increases the awareness of IT services costs and the proper use of IT's resources. It is believed, that more accurate cost data will improve the quality of decisions concerning IT services.

1.1 Background

Finnish higher education consists of traditional research universities and universities of applied sciences. The focus of research universities has been in research and in creation of new knowledge, whereas the universities of applied sciences focus on applying existing knowledge in cooperation with work life. Metropolia University of Applied Sciences is the largest university of applied sciences in Finland. Metropolia grants Bachelor's and Master's degrees in the fields of Business, Culture, Health Care and Social Services, and Technology. Some of the key facts describing Metropolia include:

- 16 700 students and 1 000 staff
- 2 560 Bachelor's and 410 Master's graduates in 2016
- 67 degree programmes, of which 12 in English
- Business: 1800 students, 6 degree programmes
- Culture: 1800 students, 14 degree programmes
- Health Care and Social Services: 4900 students, 23 degree programmes
- Technology: 8200 students, 24 degree programmes
- Most popular university of applied sciences in terms of applicants
- 900 foreign degree students
- Budget in 2017 95 million euros (Metropolia, 2017a)

Finnish higher education sector has long history on IT co-operation. For example, joint IT software development between Metropolia University of Applied Sciences and Tampere University of Applied sciences started already in 2003. Over the years, the number of joint software and development projects have increased. One of the best examples demonstrating the power of co-operation is the Peppi software ecosystem for higher education management and planning. (Peppi-konsortio, 2017) Peppi started as a project in 2010 and is currently managed and developed through the Peppi consortium, founded in 2013. Peppi ecosystem has been widely adopted among Finnish higher education institutes, covering 74% of students in universities of applied sciences and 56% of students in universities. (Orama, 2017)

In addition to software development projects and co-operation in procurement, there have been discussions and a project on the possible establishment of shared service center that would provide basic infrastructure and common to all end user IT services for all universities of applied sciences. A feasibility study was conducted and the proposal was found to be promising, after which a business plan was drawn up. Time was not ripe yet for such radical change but nonetheless there may be a valid business case for own IT service production in higher education sector.

One of the factors driving co-operation and increased interest in IT costs is the declining government funding of universities. Figure 1 illustrates the development of government funding and total operating costs in Metropolia for the period of 2008 - 2016. (Opetushallitus, 2017; Metropolia, 2017b) State budget cuts and changes in the financing model of universities of applied sciences have led to noticeable decrease in government funding, whereas total costs have remained at a level of around 100 million euro. In 2016, 15% of total cost had to be covered by other sources of funding. It should be obvious, that IT can be of great help in filling the gap. On the cost side of the equation, productivity can be increased by means of more efficient use of modern IT systems supporting streamlined processes, and revenue can be increased through the sale of IT services, preferably as much value-added as possible.

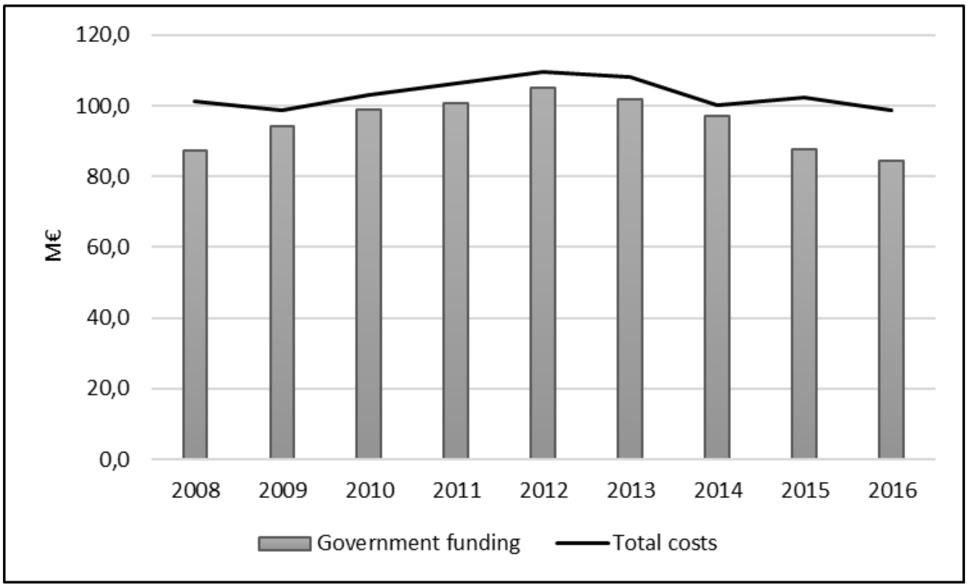

Figure 1: Government funding and total costs of Metropolia UAS

1.2 IT Services’ organization

IT services in Metropolia are organized as illustrated in figure 2. CIO is responsible for the IT Services support unit, comprising of three teams. In short, System Maintenance is responsible for the IT infrastructure, ICT Support for end user support and end user computing, and Information Management and System Services for software development and project management. Each of the teams are also individual cost centers. Regarding this thesis, System Maintenance is responsible for all of the production activities for server virtualization service. Most of the operating and investment costs are registered at the System Maintenance cost center. Rents and some other minor costs, however, are costs of Financial and Administrative Services.

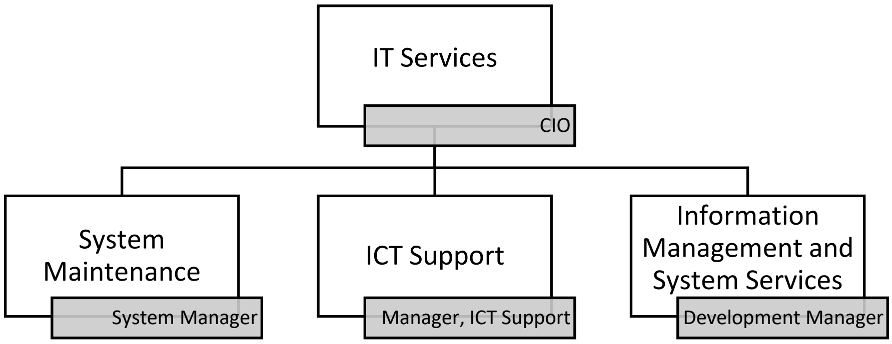

Figure 2: IT Services' organization

1.3 Server virtualization service

As stated before, server virtualization service was chosen as a case project because of its key role in IT service production. Figure 3 illustrates a high level logical overview of the IT infrastructure and services. Server virtualization service provides a computing platform used by upper layer end user IT services. Server virtualization depends on the underlaying physical resources, such as servers, network, storage and facilities.

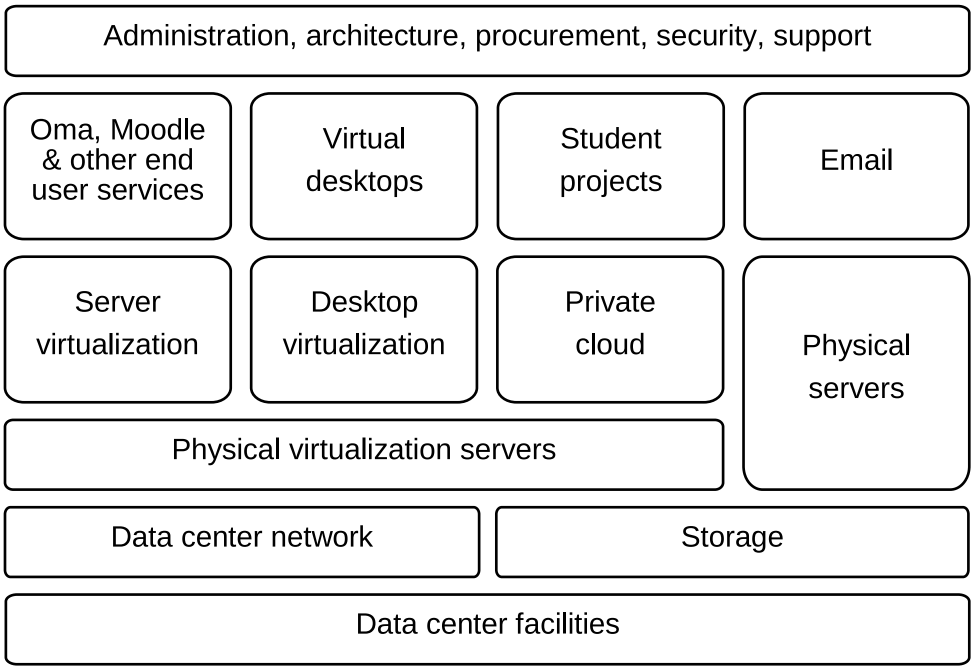

Figure 3: Logical overview of IT infrastructure and services

In the case of server virtualization, System Maintenance is responsible for practically all of the IT related activities from administration to data center facilities. From a cost perspective, common to all layers is labour cost. Each individual layer in the infrastructure incurs its own specific costs. Facilities costs include rent, electricity and outsourcing costs for maintenance. In addition to labour and facilities costs, IT equipment costs comprise of electricity, depreciations for hardware and software, and support services.

2 Business problem

This chapter discusses the motive for this thesis; what are the challenges in current situation and how this thesis aims to address them.

2.1 Challenges in current situation

Many of the challenges in present situation regarding IT costs are derived from the fact that IT costs have not been much of an issue until of lately and any thorough IT cost analysis have not been carried out before.

The list of shortcomings resulting from the lack of valid and reliable cost information includes, but is not limited to, at very least the following.

- The cost-effectiveness of own IT service production cannot be compared with confidence to other universities and commercial service providers.
- No informed make-or-buy decision on IT service production can be made.
- There is no sound basis for production cost when determining the selling price for a service.
- Regarding IT cost chargeback and budgeting, there is no monetary measure how much each support unit and degree programme consumes various IT's resources.
- Targeting budget cuts without knowledge of both costs and resource usage is arbitrary and unfair.

2.2 Research questions

The main research question this thesis aims to investigate and answer is:

1. How to determine a valid and reliable total cost for the server virtualization service?

In addition, suggestions are sought to the following questions:

2. How the IT service cost accounting can be further improved?
3. What can be concluded on the economic feasibility of selling the service provided or providing the service through shared service center?

The answer for the main research question is valuable in itself in internal decision-making and is needed to answer the additional research questions. The answer to second question discusses how the reliability and validity of the product costs can be further improved and are there any issues requiring special attention. The third question connects the internal operations examined in this thesis to a broader national context, where there is long history in joint IT projects and more recently, also an increasing pressure for cost savings and finding sources of external funding.

2.3 Objective and outcome

The objective of this thesis is to determine the cost of server virtualization service in Metropolia University of Applied Sciences. The outcome is a valid and reliable presentation of the total cost for the server virtualization service. In addition, this thesis provides visibility into the IT infrastructure cost structure and further knowledge on possibilities of expanding the service production both internally and at a national level.

3 Research process

In this chapter, the research methods used in this study are discussed. First, the research method applied is explained, followed by a discussion of research design and data.

3.1 Research method

While the objective of this thesis is to determine the cost of a particular IT service in an individual organization, a case study is a strong candidate as a research method. According to Yin (2014, 4), the more the research seeks to explain some present phenomenon or the more in-depth exploration is required by the research questions, the more relevant a case study method will be. Specifically, a case study is to be used, when the research question is in the form of *how or why*, when control of behavioural elements is not required and when the research focuses on contemporary events (Yin, 2014, 9).

A case can be an organization or part of it, product, service, function or process. The case study provides information on the phenomenon in its actual situation and operating environment. Case study as a research method aims to provide in-depth and detailed information about the case being investigated. In a case study, it is more important to find out a lot of a narrow scope than little from a broad scope. The case is not a sample of a larger group, nor does the research aim to generalize. A case study typically explains how something is possible or why something happens. (Ojasalo, Moilanen & Ritalahti, 2014, 52-53

Case study method has been traditionally associated with number of concerns. For example, many researchers have had the concern that case studies are not rigorous enough, i.e. the case study researcher has been sloppy, not used systematic methods or allowed ambiguous evidence to influence conclusions. Another concern has been the inability to generalize from the findings of a single case study. Yet another valid concern is that case study research can take a long time and lead to overwhelming amount of material. (Yin, 2014, 19-22) All of these concerns require attention in the research design of this thesis. The decision has been made to provide adequate discussion of the methods used and to collect sufficient amount of data in order to assure the reader of the reliability and validity of the outcome.

Case study as a research method applies well in this thesis, as the purpose is to address a narrow scope business problem regarding given case and organisation. In order to answer the research questions, a thorough analysis of IT costs and cost structure is needed. A valid and reliable presentation of the total cost requires gathering as much cost and volume data as is economically feasible. However, the limitations of the method and applicability of the results in other situations must be understood. The purpose of case study is to explore given case in a well-defined context. Therefore, neither case study in general nor the methods and results of this thesis cannot be generalized – they apply only in this particular case. In addition, there is no single accounting theory to be applied without modifications. The product cost calculation involves choices made by the accountant and the result is always somewhat subjective. In other words, if another researcher would apply the same data and develop the conceptual framework, the end result will most certainly be somewhat different.

With all its limitations, the case study in this thesis will be constructed in such a way, that the methods and results would be as exploitable as possible. To achieve this, the conceptual framework will be discussed in detail to explain the choices made. In data collection, all the relevant raw data on costs and volumes will be presented in product cost calculations. While the case study in itself is not generalizable, the methods used should be relatively easy to modify to be applicable in another similar situation. In addition, with all the relevant data, one can make own adjustments to the product cost subject to need. Using the methods and data as a starting point, it should be straightforward to determine the cost of other individual IT services provided by IT Services unit. Thus, a case study is by no means a sloppy method; instead, a systematic and objective mind of the researcher is to be applied.

3.2 Research design

General design of a case study includes the following five components:

- Case study’s questions. As discussed, the research question typically answers the question how or why. In this thesis, the research represents a single case with narrow scope.
- Case study’s propositions or objectives. These will guide the research towards particular aspect of the research question and how it may be explored. In this thesis, focus is on proper accounting methods and sufficient data.
- Case study’s unit of analysis. The research design needs to define boundaries for the research. In this thesis, the unit of analysis is strictly defined cost object, whose costs are primarily registered in a single cost center.
- Linking data to propositions. This refers to data analysis. In this thesis, data availability and the IT service production environment have a significant bearing on the development of the conceptual framework. The approach is therefore inductive, where data is used in theory generation.
- Interpretation of findings. Also in this thesis, the discussion on rival explanations of findings is critical to ensuring the quality of research. (Yin, 2014, 29-36; Farquhar, 2012, 35)

Figure 4 presents the research process. Firstly, the business problem will be discussed, and the research questions and objective of this thesis are set up. Current state analysis includes discussion of the present state regarding product cost knowledge and presentation of currently available product cost data. Starting from current state analysis, IT cost and volume data will be used throughout this thesis. Conceptual framework addresses the question of how the product cost will be determined, after which the core of this thesis, the product cost calculations, will be presented. The product cost calculations answer the primary research question of this thesis. There is no single answer to product cost and hence, the product cost data presented will be discussed. The product cost analysis completes the big picture on the theme of different cost for different purpose and enables to answer the secondary research questions.

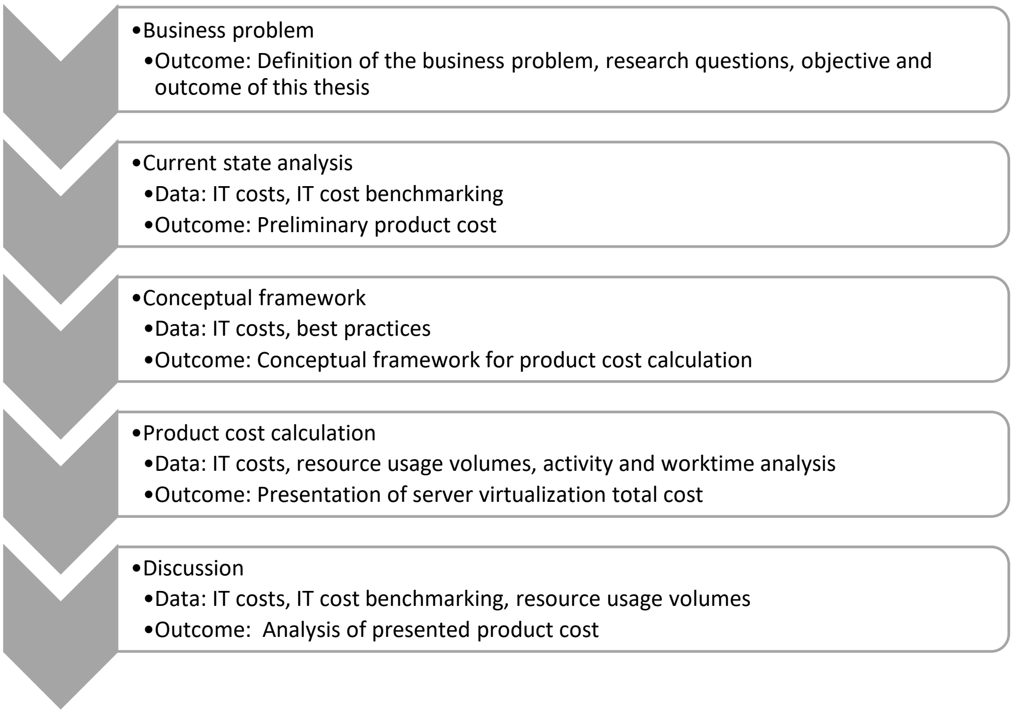

Figure 4: Research design

3.3 Data collection and analysis

Quantitative cost, volume and worktime data related to IT services is collected and analysed throughout the phases described in research design. In addition, qualitative data in the form of best practices will be collected in developing the conceptual framework, and in the form of activity analysis in product cost calculation. Data sets used in this thesis are introduced in this chapter and discussed further on subsequent chapters.

Internal IT cost information will be first collected in current state analysis and used throughout the research. IT cost data is sourced from bookkeeping and invoicing systems. Internal IT cost data comprises of balances of IT related accounts and invoices for equipment and services purchases. External IT cost benchmarking data will be collected from BencHEIT survey and service provider’s price lists.

Best practices will be collected from literature when developing the conceptual framework. Real life cases of activity-based costing are especially important raw material in order to develop a proper accounting model to assign fair share of data center network costs to server virtualization.

Interviews of System Maintenance employees will be performed during the determination of labour costs. Team level activities are analysed and defined, after which team members are interviewed in order to determine the amount of worktime spent on each activity.

The usage of various IT infrastructure resources will be collected during product cost calculation and discussion phases. Resource usage data is sourced from resource specific measurements. The measurement is used either as it is or as an average of multiple measurements. For example, the amount of data center floor space is constant but number of virtual machine and tens of other variables describing infrastructure resource usage varies over time, and hence, averages are widely used. The quantitative cost data is manually collected from financial administration systems and IT equipment into MS Excel spreadsheets, which is also used for further analysis.

Most of the data used in this thesis is regarded, in principle, valid and reliable. By default, there is no reason not to trust bookkeeping records or volume data collected from IT equipment. When estimations have to be made or data reliability is questionable, these concerns are expressed explicitly. Data quality is further discussed when collected and analysed.

4 Current state analysis

This chapter includes a brief description of current state regarding IT service cost accounting and a discussion on what can be concluded on the cost of server virtualization based on currently available cost information.

4.1 Current situation in IT service cost accounting

The present situation and challenges regarding IT service cost accounting was discussed in the chapter on business problem. Thorough and systematic IT service cost accounting have not been performed, with the exception of specific cases, where costs have had to be estimated. For example, major IT projects have included some form of cost analyses and e.g. cost of server virtualization have been roughly estimated. However, Metropolia's IT Services have been active in the field of IT cost benchmarking. Metropolia has participated in the BencHEIT survey for several years. BencHEIT is a European level survey for higher education institutes for IT costs and volumes (Eunis, 2017). BencHEIT survey is valuable tool in high level costs analysis and comparison. For example, survey results reveal IT budget allocation among various service categories and trends over time. BencHEIT is discussed later in the next chapter.

4.2 Available cost data and preliminary product costs

Metropolia's financial management practices split costs into two pools, namely annual operating costs and investment costs. Both of these are also budgeted separately. Table 1 presents actual annual operating cost data for System Maintenance team for year 2016. Data is sourced from bookkeeping and all costs are accounted for in product cost calculations. In this thesis, all costs are VAT 0%. Personnel and connectivity costs represent 81% of total annual operating costs. There have been no major changes in personnel or other operations since the start-up of Metropolia in 2008, hence the annual operating budget has been in the order of 900 000€ every year. Therefore, the use of last year's annual cost data is an accurate and reliable starting point for further labour and overhead cost calculations.

Table 1: Operating costs of System Maintenance

Account	Cost	%
Personnel costs	444 718 €	48 %
Fibers and connectivity	310 494 €	33 %
IT software support	75 585 €	8 %
IT equipment support	61 270 €	7 %
IT accessories	8 965 €	1 %
Training	8 741 €	1 %
IT consulting services	6 661 €	1 %
Travel	5 864 €	1 %
Telephony	2 974 €	0 %
End user devices	2 966 €	0 %
Other	914 €	0 %
Total	929 152 €	100 %

It is important to note, that income statement for System Maintenance does not include IT equipment and software depreciations. Depreciations are treated as Metropolia-level costs, they are not presented in cost center level income statements. In order to get an overview of System Maintenance total annual costs, the annual investments and their estimated depreciations have to be taken into account. Table 2 presents System Maintenance total investment costs for last five years. Most of the equipment invested in have a lifetime of five years. Using straight-line depreciation gives an average annual depreciation of 630 270€.

Table 2: Investment cost of System Maintenance

Year	Investments
2016	879 794 €
2015	978 221 €
2014	425 886 €
2013	286 276 €
2012	581 176 €
Total	3 151 352 €
Average depreciation	630 270 €

Combining the afore-mentioned data in tables 1 and 2 results in an annual total cost in the magnitude of 1,5M€.

Table 3 presents the cost structure. The total cost of 1,5M€ including average depreciation of 0,6M€ is not used in any product cost calculations, since more accurate data can be obtained. Annual investments include not just data center equipment used in IT service production relevant to this thesis but also campus network devices, videoconferencing and other non-data center equipment. The purpose is to give a notion of the cost structure and help to estimate an approximate cost of a virtual server, the main cost object of this thesis. First rough estimate can be made by dividing total cost by number of logical hosts in data center used for end-user services. Logical hosts are physical servers, virtual servers and virtual desktops. Assuming that there are roughly 700 logical hosts, the unit cost would be 2228€ per host per year.

Table 3: Cost structure of System Maintenance

Cost item	Cost	Total	%
All personnel costs			
Personnel costs	444 718 €		
Training	8 741 €		
Travel	5 864 €		
Telephony	2 974 €		
End user devices	2 966 €		
Other	914 €		
Personnel total		466 177 €	30 %
Connectivity			
Fibers and connectivity	310 494 €		
Connectivity total		310 494 €	20 %
Service production			
Depreciations	630 270 €		
IT software support	75 585 €		
IT equipment support	61 270 €		
IT accessories	8 965 €		
IT consulting services	6 661 €		
Service production total		782 751 €	50 %
Total		1 559 422 €	100 %

Another readily available source for IT cost data is the annual BencHEIT survey, which presents the total IT costs and their allocation to various service categories. Survey data consists of both operating and investment costs, and for both centralized and decentralized cost centers. The primary source of data is also bookkeeping and invoicing systems, but especially with decentralized costs incurred in degree programmes, estimates of e.g. labour usage has been made. Therefore, resulting total costs for services may not be completely accurate. Table 4 presents high level costs for various service categories in Metropolia in year 2016. (Metropolia, 2017c)

Table 4: IT costs of Metropolia UAS in BencHEIT 2016 survey (Metropolia, 2017c)

Service	Cost
Infrastructure	796 236 €
Workstations, client and peripherals	1 224 751 €
IT Service Desk / Helpdesk (incl. Service Point)	512 308 €
Data networks: LAN & WAN	937 940 €
Voice services	374 108 €
Business applications	4 088 779 €
IT management, administration and information security and enterprise architecture	486 330 €
Audio visual services	225 650 €
Other or unspecified services	122 906 €
Total	8 769 006 €

In addition to costs, in volume data Metropolia reports having 394 virtualised servers. In BencHEIT survey, most of the costs related to virtual servers are reported in infrastructure costs. Using similar division as with income statement and investment cost data, a rough estimate of the unit cost of a virtual server can be obtained by dividing infrastructure cost 796 236€ by 394 virtual servers, the result being 2021€.

An average of the two previously calculated unit cost figures would be 2125€. Clearly, the actual unit cost for virtual server must be well below this figure, since System Maintenance resources are being used for many other services as well. This example also demonstrates why calculating unit costs simply by dividing costs with volumes will lead to erroneous results. This happens because using volumes as cost-allocation base does not take into account the fact that various services consume unequal amounts of resources and activities.

5 Conceptual framework

In this chapter, the conceptual framework necessary to compute the product costs is introduced. The conceptual framework consists of theories and concepts applicable in this particular case. Cost terminology is discussed with examples related to actual IT environment.

5.1 Competition, value chain and competitive advantage

Although the topic of this thesis is primarily involved with cost accounting, the third research question cannot be answered without touching competition and competitive strategies. This chapter includes only brief introduction of the most important concepts of competitive strategies in order to connect competitive advantage with activity-based costing.

Oxford dictionary defines the word competition as an activity to win something over others. Companies compete all the time in the market place, and in the case of server virtualization, Metropolia's offering would compete with that of Amazon and Microsoft. Competition is examined through the five competitive forces, illustrated in figure 5, which determine the attractiveness of an industry for a long-term profitability. (Porter, 2004, 3-5)

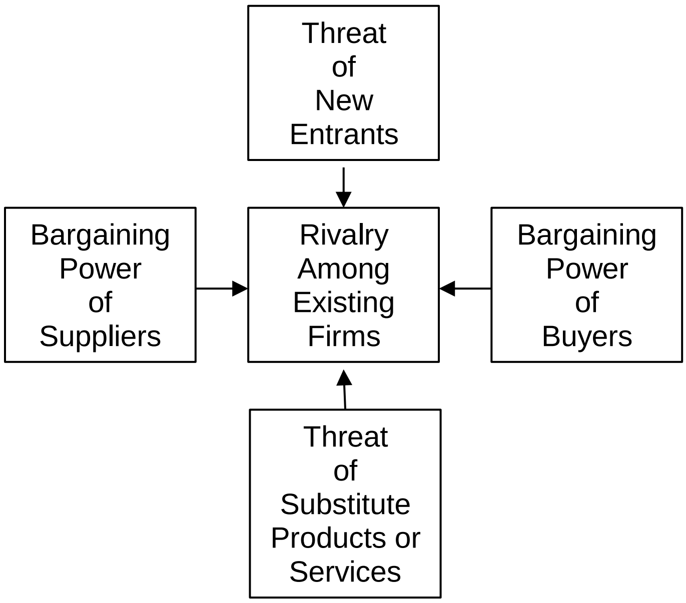

Figure 5: The five competitive forces (Porter, 2004, 5)

Whether the IT services produced by Metropolia, or by a shared service center, can be produced and sold profitably to other universities over long term, depends on the producer's ability to gain sustainable competitive advantage over other producers. Company's ability to manage the five competitive forces better than others can lead to two types of competitive advantage, either low cost or differentiation. Competitive advantage is pursued through a competitive strategy. The three generic competitive strategies proposed by Porter are low cost, differentiation and focus, as illustrated in figure 6. (Porter, 2004, 11-12)

COMPETITIVE SCOPE		COMPETITIVE ADVANTAGE	
		Lower Cost	Differentiation
	Broad Target	1. Cost Leadership	2. Differentiation
	Narrow Target	3A. Cost Focus	3B. Differentiation Focus

Figure 6: Generic competitive strategies (Porter, 2004, 12)

For example, if it is determined after analysing the industry competition, that the company cannot position itself as a cost leader, then it must seek ways to differentiate its offering. If the company's offering is unique and valued by customers, it may be able to execute profitably the differentiation strategy. If not, it may still be able to compete with narrow scope. In the focus strategies, the company positions itself to serve a narrow segment, where it seeks either cost leadership or differentiation within the target segment. (Porter, 2004, 14-15)

In order to understand the sources of competitive advantage, the concept of value chain is introduced. Value chain is a systematic method to analyse company's activities to identify the sources of competitive advantage. Value chain represents all the activities required from the design of a product to delivery of final product to the customer. Analysing activities is required to understand costs and the sources of differentiation. A company performing the necessary activities more cost-effectively or better gains competitive advantage. Each activity in the value chain should add value to the product. Company is profitable, if the value created to customer exceeds the costs of performing the activities. Value is the price the customer is willing to pay for what the company offers. Figure 7 illustrates the generic value chain. (Porter, 2004, 33-38)

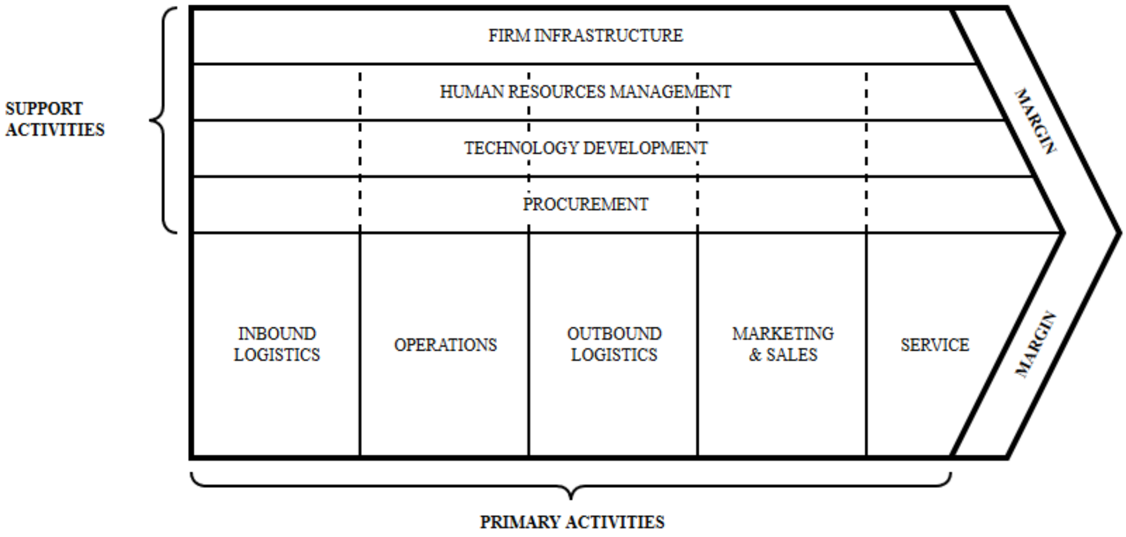

Figure 7: The generic value chain (Porter, 2004, 37)

An application of the generic value chain is used in this thesis and discussed in subsequent chapter on product cost

5.2 Cost terminology

This chapter introduces key cost terms and gives examples of their use.

5.2.1 Cost definitions

A **cost** can be defined as the amount of resource used to achieve a given goal, expressed in monetary terms. Historical costs are **actual costs** and planned or forecasted costs are **budgeted costs**, both of which are needed in decision making. For example, the comparison of actual costs to budgeted costs reveal how well product costs were controlled and helps to spot areas where improvement may be needed. **Cost object** can be anything for which cost information is needed. Table 5 illustrates examples in the context of Metropolia's IT services. (Horngren, Datar & Rajan, 2015, 51)

Table 5: Examples of cost objects

Cost object	Example
Service	Virtual machine, email account, end user support
Project	Renewal of blade server or data center network infrastructure
Customer	All users, users of certain degree programme, external customers
Activity	Data center network, server installation, OS update
Department	IT Services, System Maintenance, Helpdesk, faculty, support services unit

The cost of a cost object is typically determined by first accumulating costs and then assigning them to cost objects. **Cost accumulation** refers to collection of cost data and happens usually in an accounting system, but as in this case, cost data is collected from other sources as well. Costs incur e.g. from hardware and software investments, labour, facilities and electricity. After collecting total costs, they are **assigned** to cost objects, such as end user IT services or infrastructure related activities. (Horngren et al, 2015, 51)

5.2.2 Direct and indirect costs

The categorization of cost as either **direct** or **indirect costs** depends on how they can be traced to cost objects. Direct costs can be easily and cost-effectively associated with cost object, whereas indirect costs cannot. **Cost tracing** refers to assignment of direct costs to cost objects. For example, the cost of physical virtualization server and the maintenance work required to install virtualization software security patches can be easily traced to server virtualization and therefore are direct costs. On the other hand, salary of the CIO and facilities rents are related to server virtualization but also to every other service offered by IT Services department and there is no cost-effective way to trace part of salary or rent to a virtual server. Managerial and facilities costs are therefore indirect costs. **Cost allocation** refers to assignment of indirect costs to cost objects, implying non-traceability. (Horngren et al, 2015, 52)

Cost assignment refers to both tracing of direct costs and allocation of indirect costs, and it can be a challenging task. Direct costs have clear cause-and-effect causation and are more accurate. For example, the purchase price of virtualization server is well documented in the original invoice available in the invoicing system. The life cycle of the server is defined at the time of purchase; therefore, the amount of depreciation is completely accurate. By contrast, there is no single answer on how to allocate indirect costs.

Referring to server virtualization, one of the key questions is on what basis should data center costs be allocated to the server virtualization service. Possible cost allocation bases are many and as the share of data center network is substantial in total product cost, care must be taken in choosing proper accounting methods in order to avoid erroneous product costs. (Horngren et al, 2015, 53)

Same cost can be both direct and indirect cost, depending on what the cost object is. As previously illustrated, CIO's salary is indirect cost, if the cost object is server virtualization, but direct cost, if the cost object is the IT Services department as a whole. The division into direct and indirect costs is affected by number of factors. If the amount of cost is small, it may not be economically feasible to trace it as a direct cost and the cost is allocated as indirect cost. On the other hand, the use of modern IT systems and e.g. bar codes make it possible to trace even the smallest costs as direct cost, without introducing expensive manual labour. In addition, the design of operations can help in assigning costs as direct costs. If, for example, certain office building is used by only one department, all the facilities costs of the office building are direct costs of the department in question. (Horngren et al, 2015, 53)

5.2.3 Variable and fixed costs

Costs differ also in their behaviour. **Variable cost** changes in proportion to output volume, whereas **fixed cost** does not change for a given time period. For example, if each additional virtual server ordered requires manual setup activities, the number and total cost of these activities increase as the number of ordered new virtual servers increase. These setup costs vary in relation to output volume and are variable costs. Fixed costs remain the same through the time period, they do not vary in relation to output. For example, data center facilities rent remain unchanged regardless of the number of virtual servers running. (Horngren et al, 2015, 54)

Cost behaviour pattern can also be **semi-variable**, where there is both a fixed and variable component in the cost. For example, telephone costs consist of fixed monthly fee and variable cost per minute. **Relevant range** is the range of normal volume where there is a relationship between the volume and cost. For example, the cost of physical virtualization server is fixed up to maximum capacity, whether there are zero, one or maximum number of virtual servers running, and for the life cycle of the server hardware, in this case four years. Fixed cost changes, when new servers are purchased at the end of current server's life cycle. Relevant range applies also to variable costs. For example, material cost may decrease after a certain volume due to price discount. In this thesis, the costs of physical virtualization servers along with the share of blade server infrastructure and server specific virtualization software licences running the virtualization layer are handled as semi-variable cost. The physical server can run certain number, or batch, of virtual servers and after capacity thresholds are reached, a new physical server with required licenses must be added. Server costs are therefore fixed up to the threshold, after which they increase to a new fixed level as a result of increased number of virtual servers. (Horngren et al, 2015, 57)

Table 6 illustrates the preceding discussion in the context of server virtualization. Cost object is a virtual server and costs are grouped by behaviour pattern and assignment type.

Table 6: Examples of cost objects by behavior and type

	Direct costs	Indirect costs
Variable costs	Backup capacity Storage capacity	Electricity
Semi-variable costs	Backup software Virtualization servers Virtualization software	
Fixed costs	Direct labour	Data center facilities Data center network General overhead Monitoring Server infrastructure Storage infrastructure

Cost behaviour depends on the time frame concerned. In Metropolia's case, data center facilities rents are fixed in short to medium term but may become variable, when time frame is long enough. Also, costs cannot be simply assumed to be either variable or fixed by nature. Personnel costs may seem variable, as demand for work increases when demand for end products increases and vice versa. However, personnel costs in Metropolia are in practice fixed costs, as for non-economic reasons the number of personnel cannot be reduced even if demand for work decreases. The division of costs into variable and fixed cost is important in pricing decisions. The selling price or internal transfer price should cover at minimum the marginal cost in short term and, obviously, all costs in the long run.

Cost driver is a variable, that has a causal relationship between change in cost and change in activity or output volume in a given time frame. (Horngren et al, 2015, 56) Cost driver can also be described as an event causing a cost to incur. When costs have common cost drivers, all these costs are accumulated in a cost pool. (Ellis-Newman & Robinson, 1998, 374) For example, the amount of maintenance work required to support virtualization layer and license costs increase as number of virtualization servers increase, so the number of virtualization servers is a cost driver of virtualization layer. The cost driver for virtualization servers is the number of virtual servers, as the amount of virtualization servers is determined by the number of virtual servers needed in total.

5.2.4 Total costs and unit costs

Unit or **average cost** is obtained by dividing total costs by number of units. For example, if total costs of a server virtualization would be 270 000€ per year and the system is capable of running 300 virtual servers, then the unit or average cost of these virtual servers would be 900€ per year and 75€ per month. Unit cost is essential in many decision-making situations, for example, when determining possible selling price for virtual server or in comparison to other vendor's offerings. Unit costs are found through the virtual server value chain, where all infrastructure activities and resources have their own unit costs. Summing these up will lead to total unit cost of a virtual server. (Horngren et al, 2015, 58)

Unit costs must be evaluated cautiously, as they are dependent on volume. In the previous example, the 300 virtual servers could have been the systems maximum capacity and the obtained unit cost of 900€ per year could have been used as a production cost in pricing. Now, if it would turn out that the actual maximum capacity is only 250 virtual servers, then the unit cost would rise to 1080€ per year, an increase of 20%. Therefore, costs have to be analysed thoroughly, as errors like this can easily lead to losses. As a general rule, costs should be thought of in total variable costs, total fixed costs and total costs, and unit cost should be calculated, when specifically needed. (Horngren et al, 2015, 59)

5.2.5 Cost pool and cost-allocation base

Cost pool is a group of multiple indirect cost items. (Horngren et al, 2015, 130) Cost pool can be very general, when all overhead costs of broad activities are accumulated into single cost pool, or more detailed, when activities are separated into individual cost pools. The more there are separate cost pools, the more reliable the result is. (Ellis-Newman & Robinson, 1998, 374). In the case of server virtualization, the data center network is an example of a rather complex cost pool, comprising of several individual cost items and cost pools of different type.

Cost-allocation base is a device to link the indirect costs to cost objects. A typical example of cost-allocation base from the manufacturing sector would be machine-hour. If the total indirect cost of a machine is 500 000€ and 10 000 hours of machine time is used in the production, then the indirect cost rate would be 50€ per machine-hour and the machine-hour being the cost-allocation base. Attention must be paid in choosing the cost-allocation base. The cost driver of indirect costs should be used as cost-allocation base because of the direct cause-and-effect relationship between the cost-allocation base and the indirect costs. In the manufacturing example, the machine-hour is ideal cost-allocation base if costs increase the more the machine is used in production, and if time is a proper indicator of the machine usage per produced unit. (Horngren et al, 2015, 130)

5.2.6 Product cost

According to Horngren et al. (2015), "*a **product cost** is the sum of the costs assigned to a product for a specific purpose*". The definition highlights the fact that product cost varies depending on the use case, hence the principle "different product costs for different purposes". The definition of product cost is discussed using the Porter's value chain as a framework of activities. Figure 8 illustrates an application of Porter's generic value chain. The product cost varies according to which business functions are to be included. When making decisions on pricing and product-mix, the product cost represents the total cost including all functions through the value chain. On the other hand, the allowed product cost may include only part of research and development, design and production cost when dealing with government contracts. And in a manufacturing company, the product cost appearing in the financial statement contains only inventoriable production costs, representing the cost of goods sold when sales occur. (Horngren et al, 2015, 59)

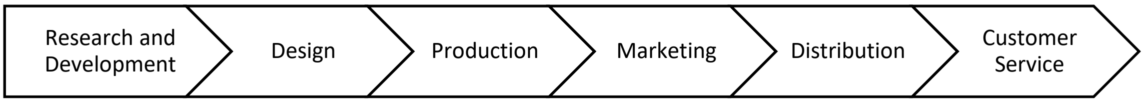

Figure 8: Value chain (Horngren et al, 2015, 28)

In principle, the product cost of a virtual server in this thesis represent a total cost including all business functions. That said, there may very well be minor costs not included, but the principle is that all expense items of server virtualization and all costs of System Maintenance team are definitively included. Cost data for less significant items are either estimated or gathered to the extent of economic feasibility. In the following, costs of all the business functions are discussed in the context of Metropolia's IT Services and server virtualization service. A major point to note is that the product cost in this thesis is determined for the purpose of internal decision making. Therefore, adjustments will be needed in other applications, e.g. when preparing financial statement. All the cost data is discussed further in the subsequent chapter on product cost calculation. All activities and costs discussed belong to System Maintenance cost center, unless otherwise noted.

Research and Development include costs of developing new services and processes. The server virtualization platform, along with all the production infrastructure, is fairly stable as a whole, but smaller improvements are developed and implemented every year. The technological infrastructure itself develops, requiring updates and sometimes topology changes. User's needs are also major impulse for development, as new end user IT services are introduced and the contents in degree programmes are constantly revised, possibly requiring a new type of IT service or a process change.

Design of services and processes include all the costs related to planning and testing of services and processes. Typical example would be virtualization software update or upgrade, requiring e.g. study of release notes, testing the update and planning the update in the production environment.

Production includes the activities and costs required to keep the server virtualization service up and running, and is the function where most of the product costs are introduced. Both the virtualization layer including hardware and software, and the actual virtual servers involve routine maintenance tasks. Server and storage capacity is added and virtualization software is updated from time to time. Maintenance includes also incident handling for virtualization layer and virtual servers. Some production related costs, such as facilities and electricity, are registered as costs of other cost centers than System Maintenance.

Marketing is to be understood more of a co-operation effort with internal stakeholders, rather than external marketing in the traditional sense of the word. For example, marketing activities involves informing faculty staff of new developments and possible use cases in the field of server virtualization. Another area of co-operation is joint IT projects with participating universities of applied sciences, where server capacity may be provided by System Maintenance.

Distribution function is straightforward and simple, as vast majority of the virtual servers are ordered and used by IT Services staff and the outbound logistics consist of practically an email stating necessary technical details. Most of the virtual servers used by students are provided in a private cloud service, where the orderable virtual servers are standardized and distribution process following a user generated order is fully automated.

Customer service function provides the necessary support services for server virtualization service. Support service in this case applies to virtual servers, including the virtual machine and operating system, and the role of user in need of support is that of system administrator. In other words, customer service of server virtualization includes neither the activities nor costs associated with support for the actual IT services consumed by end users.

Finally, the product cost in this thesis is discussed in relation to financial reporting. As stated before, the product cost includes all costs and in theory, cannot be used in financial reporting without adjustments. In income statement, production costs appear as cost of goods manufactured under cost of goods sold. Costs of all other business functions, namely research and development, design, marketing, distribution and customer service, are treated as period costs after gross margin. In the case of server virtualization, however, the product cost presented may be thought of as equal to cost of goods manufactured. First of all, in the case of services, there is no inventory and hence no inventoriable costs. Possible inventory would contain only purchased but not yet installed IT equipment, but even these equipment, analogous to materials in manufacturing company, are taken into use upon arrival. In the absence of inventories, cost of goods manufactured equals cost of goods sold. All expense items in the product cost, with the exception of labour cost, are completely involved with production activities. If a pure cost of goods manufactured is needed, then the labour cost for research and development, design, marketing, distribution and customer service activities need to be subtracted from the product cost. The other business functions incur no other costs than labour, there is no outsourcing costs for marketing et cetera. If it is assumed that a maximum of 20% of the labour may fall upon the other business functions than production, and thus subtracted, the product cost would decrease by 2%. Therefore, at least 98% of the product cost would represent the cost of goods manufactured. Furthermore, some minor cost items are estimations and depreciations are handled according to actual equipment specific life cycles, rather than depreciating all IT equipment in four years as in the official financial statement. These departures are discussed in detail in subsequent chapter on product costs and must be taken into account in regard to financial reporting. (Horngren et al, 2015, 61-64)

5.3 Traditional cost accounting methods

Commonly used, traditional cost accounting methods include process costing and job costing. In this chapter, these traditional methods are discussed, followed by a separate chapter on activity-based costing. A brief introduction of each is provided, along with examples linking the method with application in the case of server virtualization. The primary purpose of cost accounting methods discussed is to assign indirect cost to cost objects, although principles of process costing are widely used to compute unit cost of various infrastructure resources, where most of the costs of a given cost object are direct costs. As will be seen, there is no single method which would apply in all situations. Instead, the final product cost calculation is a hybrid of accounting methods and principles best applicable in each individual cost assignment task. The theoretical framework on each is discussed in general, and the actual accounting methods used are discussed in detail in chapter on product costs. Activity-based costing especially is a more complex approach, where the discussion involves only high-level principles and where the application in practice is highly dependent on the actual production environment.

5.3.1 Direct costs

The first major accounting principle followed, before the application of costing methods discussed later on, is that of tracing as much of the costs as direct costs as is economically feasible. Direct costs can be reliably traced to cost object, while indirect costs are allocated using some intermediary device. The accuracy of allocation depends on how well this device manages to link the root cause of the indirect costs to the cost object. Therefore, the greater the share of direct costs, the more accurate the product cost will be. In addition, if most or all costs could be identified as direct costs, there would be little or no need to complex costing methods necessary to allocate indirect costs. (Horngren et al, 2015, 179)

5.3.2 Process costing

Process costing is appropriate in situations, in which masses of identical or similar products or services are produced. Process costing is typically found in manufacturing companies, especially in mass-production. Industries using process costing include food, textile and oil-processing. In the simplest case with no inventories, unit cost is calculated by dividing total costs by the number of units produced in a given accounting period. In the unit cost, all direct manufacturing costs and indirect overhead costs are averaged evenly to all units produced. In the case with ending work-in-process inventory, where there are some units started but not finished during the accounting period, the concept of equivalent units is needed in order to assign costs to both complete and incomplete units according to degree of completion. Finally, in the case with beginning and ending work-in-process inventory, where there are incomplete units from previous accounting period, a weighted-average or FIFO method is needed to assign costs of the work done to date in the beginning inventory. (Horngren et al, 2015, 687-698)

The principles of process costing are used on individual infrastructure expense items throughout the product cost calculations. The following example of determining the data center facilities unit cost illustrates the application of process costing. According to table 7, data center facilities have a total cost of 37635€ per year. At this point, it is sufficient to state that data center usage is best measured with number of used rack units, representing the output of data center facilities service. Dividing the total cost by 283 used rack units equals a unit cost of 133€ per used rack unit.

Table 7: Data center facilities costs

Data center facilities	
Real estate	12 855 €
Power infrastructure	10 213 €
Cooling infrastructure	9 920 €
Direct labour	3 812 €
Monitoring	488 €
Overhead	348 €
Total cost	37 635 €
Used rack units	283
Unit cost	133 €

Similar example can be made using the UCS server infrastructure. The blade server chasses and other infrastructure components needed to support the actual UCS blade and rack servers have a total cost of 29365€. There are 22 servers using the infrastructure, therefore, each must bear an infrastructure cost of 1335€ per server.

As stated before, process costing averages total costs evenly to all output units. In the case of data center facilities and many other infrastructure components, this is totally acceptable. Although it is true that a more powerful server requires more from power and cooling infrastructure than a less powerful one, it is thought that in practice each rack unit used consumes equal amount of data center resources. Were this a problem, then the power and cooling infrastructure cost should be handled separately from facilities costs and assigned using electricity consumption instead of rack units – still applying the simple technique of process costing.

5.3.3 Job costing

Job costing differs from process costing in that instead of masses of identical or similar products or services, the cost object is unit or multiple units of a distinct product or service. These distinct products or services are called jobs, hence the name job costing. Examples of jobs are car repair, marketing campaign, consulting project and ship construction. For example, a garage may repair several similar vehicles or faults per day, marketing agency may run many similar campaigns and a shipyard may build multiple cruise ships for same customer but each individual job is distinct from one to another. (Horngren et al, 2015, 130-131)

Job costing comes in the form of actual costing and normal costing. Actual costing differs from normal costing in that actual indirect costs rates are used, whereas normal costing uses budgeted indirect cost rates. As the name implies, actual costing yields to actual cost of a job. Cost data for direct material and labour cost are readily available, but the problem with actual costing is that actual indirect cost rates can be calculated only after the end of accounting period, i.e. when the total amount of indirect costs incurred is known. Therefore, actual costing is rarely used, as cost information is needed e.g. on weekly and monthly basis. Actual cost rates are computed using the following equation 1: (Horngren et al, 2015, 133)

Equation 1: Actual indirect cost rate (Horngren et al, 2015, 133)

$$Actual\ indirect\ cost\ rate = \frac{Actual\ annual\ indirect\ costs}{Actual\ annual\ quantitiy\ of\ the\ cost\ allocation\ base}$$

If actual costing were applied to the data center facilities example, the actual cost rate would equal to unit cost in process costing. The unit cost of data center facilities, as well as almost all other infrastructure costs, represent actual cost of the resource in question, as the cost data used is the cost of last purchase. Although the end result is the same, whether using process costing or job costing with actual costing, most of the infrastructure costs represent costs of continuous processes, not repeated distinct jobs.

Normal costing addresses the need of timely cost data. In regard to direct costs, there is no difference to actual costing: In both methods, direct costs are assigned using actual direct cost rates and actual quantities of cost-allocation bases. However, the indirect costs are allocated using budgeted indirect cost rates, calculated in the beginning of accounting period. Budgeted cost rates represent approximate, rather than actual, costs, but the practice eliminates the need to wait until the end of accounting period before cost rates can be calculated. Budgeted indirect cost rate is computed with equation 2: (Horngren et al, 2015, 134)

Equation 2: Budgeted indirect cost rate (Horngren et al, 2015, 134)

$$Budgeted\ indirect\ cost\ rate = \frac{Budgeted\ annual\ indirect\ costs}{Budgeted\ annual\ quantitiy\ of\ the\ cost\ allocation\ base}$$

Job costing differs from process costing also in that the calculation of product cost becomes somewhat more complex. For example, a number of source documents are needed in order to determine materials and labour time used per each individual job. In general, the workflow for job costing using normal costing is as follows: (Horngren et al, 2015, 135-137)

1) Identify the cost object
2) Identify direct costs of the cost object
3) Select cost-allocation base/s to allocate indirect costs
4) Identify indirect costs of each cost-allocation base
5) Calculate indirect cost rates per each cost-allocation base
6) Calculate indirect costs for the cost object
7) Calculate total cost for the cost object by adding all direct and indirect costs

Finally, the use of normal costing lead usually to underallocated or overallocated costs at the end of accounting period. This happens, because indirect costs are allocated using budgeted cost rates and the actual indirect costs incurred by the end of accounting period may not match the budgeted amount. There are several methods to deal with the under- or overallocated costs, among which managers must choose depending on the purpose of the adjustment and the amount of costs involved. (Horngren et al, 2015, 149-153)

A variation of normal costing exists, which can be useful in service-sector and applies well in the context of IT services. For example, in IT projects the direct labour costs may represent the largest item in total costs. In both standard forms of job costing, actual direct costs are traced to cost objects. In some situations, the tracing may become difficult. A project may include bonuses or other expense items which are known only at the end of the year, meaning that actual direct cost rates cannot be calculated during the year. In addition, the amount of work done in each month may vary significantly, possibly leading to abnormally high cost rates when fixed costs are divided by below average work hours. Therefore, using budgeted cost rates also for direct costs gives a better representation of planned labour costs. Budgeted direct labour cost rates are calculated using the following equation 3: (Horngren et al, 2015, 154)

Equation 3: Budgeted direct labour cost rate (Horngren et al, 2015, 154)

$$Budgeted\ direct\ labour\ cost\ rate = \frac{Budgeted\ total\ direct\ labour\ costs}{Budgeted\ total\ direct\ labour\ hours}$$

Total cost of a project is then calculated by adding direct and indirect costs. As with the standard version of normal costing, using budgeted cost rates lead to under- or overallocated costs, which must be taken into account at the end of the accounting period.

The objective of this thesis is to determine the actual cost of present server virtualization environment and for consistency reasons, actual costs are used when possible. Budgeted figures are used to represent the cost of some minor expense items, where actual cost is not available. However, the use of actual costs, representing past rather than future, may not be appropriate e.g. in times of changing production environment. For example, were there significant changes in labour costs, then the use of budgeted direct labour cost rates would probably better represent the direct labour costs.

5.3.4 Hybrid costing

After the discussion on process costing and different forms of job costing, it is clear that seldom a pure form of any costing system applies in real-life situations. Instead, a hybrid costing system is needed in order to match the accounting system to a given production environment. In the case of IT services, there are characteristics of mass-production, where process costing applies. Similarly, there are projects and other types of distinct jobs, where the principles of job costing are appropriate. As will be seen with the server virtualization service, product cost calculation involves the application of many different accounting methods and principles, according to the appropriateness in a given situation. (Horngren et al, 2015, 707)

5.4 Activity-based costing

Traditional costing, such as job and process costing, has been associated with number of widely acknowledged problems, which have led to development of activity-based costing. One of the problems is that too simple costing system using single volume based cost allocation base can greatly distort product costs. (Alhola, 2008, 13) This happens, because simple volume based costs drivers fail to explain the relationships between costs and the events causing these costs. (Ellis-Newman & Robinson, 1998, 379) In order to be able to present accurate cost information to support decision making on e.g. product design, pricing, marketing and operating improvements, Cooper & Kaplan (1988) proposed activity-based costing as a solution some 30 years ago. The theoretical framework introduced was simple; all activities carried out are needed to support production and these activities cause costs. As products are different and consume different amounts of activities, these differences must be taken into account.

In addition to more accurate cost information, the application of activity-based costing introduces many additional benefits. It makes the cost structure visible and may reveal hidden costs. Transparent and fair costing system helps in communicating IT costs to business unit managers consuming the services. (Gerlach et al, 2002, 66) In addition to visibility, activity-based costing can help to identify non-value-adding activities. (Suthummanon, Ratanamanee, Boonyanuwat & Saritprit, 2011, 90-91) Activity-based costing is beneficial especially in complex business environments with diverse product mix and large share of indirect costs. (Shevasuthisilp & Punsathitwong, 2009, 259) The discussion of activity-based costing will begin with a practical example, followed by key concepts comprising the theoretical framework.

5.4.1 Introduction of activity-based costing

Broad averaging used in traditional costing does not take into account varying resource consumption of different products, leading to under- and overcosting of products. The result is product cost cross-subsidization, where losses in one product are covered with profits from another product. (Horngren et al, 2015, 174)

In the case of server virtualization, the assignment of data center network costs becomes problematic with simple costing systems. First of all, within the limitations of available data on infrastructure resource usage and the scope of this thesis, it is impossible to trace the data center network costs as direct costs to a virtual server. Therefore, these costs must be allocated as indirect costs, but the use of simple accounting method with single volume based cost-allocation base leads to misleading product costs. This happens because data center network is a complex infrastructure activity, whose individual functions are being used at varying rates by different services.

Data center network costs represent a substantial share of total costs, thus care must be taken to ensure proper cost allocation. The problem with traditional costing system, and how it is resolved using activity based costing, is best illustrated with simple example from manufacturing industry. A company manufactures two products, one being a low volume product and the other a high-volume product. Product costs are first determined using traditional costing and then with activity-based costing. Production data and overhead costs are presented in table 8 and table 9. (Alhola, 2008, 58)

Table 8: Activity-based costing example, production and cost data (Alhola, 2008, 58)

Product	Machine-hours per unit	Direct labour per unit	Total production units	Total machine hours	Total direct labour	Purchase orders	Setups
Low volume	2	4	1 000	2 000	4 000	80	40
High volume	2	4	10 000	20 000	40 000	160	60
Total				22 000	44 000	240	100

Table 9: Activity-based costing example, overhead costs (Alhola, 2008, 58)

Overhead costs	
Volume based	110 000 €
Purchases	120 000 €
Setups	210 000 €
Total	440 000 €

Product cost calculation using traditional costing method is presented in table 10. (Alhola, 2008, 58)

Table 10: Activity-based costing example, product cost calculation with traditional costing (Alhola, 2008, 58)

Traditional costing	
Overhead costs	440 000 €
Machine hours	22 000
Overhead costs/machine hours	20 €
Direct labour hours	44 000
Overhead costs/direct labour hours	10 €

Unit costs using machine hours

Product	Hours	Cost	Unit cost
Low volume	2	20 €	40 €
High volume	2	20 €	40 €

Unit costs using direct labour hours (alternative)

Product	Hours	Cost	Unit cost
Low volume	4	10 €	40 €
High volume	4	10 €	40 €

Costs allocated to products			
Product	Volume	Unit cost	Total
Low volume	1 000	40 €	40 000 €
High volume	10 000	40 €	400 000 €
Total			440 000 €

Product cost calculation using activity-based costing method is presented in table 11. (Alhola, 2008, 59)

Table 11: Activity-based costing example, product cost calculation with ABC (Alhola, 2008, 59)

Activity-Based Costing			
	Volume based	Purchases	Setups
Activity costs	110 000 €	120 000 €	210 000 €
	Machine hours	Purchase orders	Setups
Cost drivers	22 000	240	100
	Per machine hour	Per purchase order	Per setup
Cost/activity	5 €	500 €	2 100 €

Cost allocation to products			
Product	Volume based	Purchases	Setups
Low volume	10 000 €	40 000 €	84 000 €
	(2000*5)	(80*500)	(40*2100)
High volume	100 000 €	80 000 €	126 000 €
	(20000*5)	(160*500)	(60*2100)

Unit costs						
Product	Volume based	Purchases	Setups	Total	Units	Unit cost
Low volume	10 000 €	40 000 €	84 000 €	134 000 €	1 000	134 €
High volume	100 000 €	80 000 €	126 000 €	306 000 €	10 000	31 €

Product cost comparison is presented in table 12.

Table 12: Activity-based costing example, product cost comparison (Alhola, 2008, 59)

Product	Traditional	ABC
Low volume	40 €	134 €
High volume	40 €	31 €

Using traditional costing, both products have the same unit cost, although produced quantity for high volume product is ten times that of low volume product. Unit costs are the same because both products consume the same amount of direct labour and machine hours per unit, which is used to allocate indirect costs. (Alhola, 2008, 59) Product cost comparison reveals one of the key problems with traditional costing, namely, the use of volume based cost driver in allocation of overhead costs into the products. This distorts the product costs because in reality, the product-related activities are not dependent on production volume. (Alhola, 2008, 61)

In traditional costing, overhead costs were allocated using single cost driver, either machine-hours or direct labour hours. Therefore, traditional costing ignores the fact that both products consume unequal amount of activities, thus overvaluing high-volume products and undervaluing low volume products. In activity-based costing, three cost drivers (machine hours, number of purchase orders and number of setups) were used to accurately allocate activity costs based on their actual consumption. Activity-based costing takes into account, that the high-volume product is more efficient in the use of purchase order and setup activities. In contrast to traditional costing, activity-based costing is based on the fact that all activities are not bounded on production volume. (Alhola, 2008, 62)

5.4.2 Allocation of indirect costs in activity-based costing

Following the practical example of problems associated with using broad averages for allocating indirect cost, guidelines for refining the costing system is introduced. Firstly, costs should be traced as direct costs as much is economically feasible, thus reducing the need to allocate costs as indirect. Secondly, the number of cost pools should be increased until they are more homogenous. Homogeneity means, that costs in a homogeneous cost pool have same or similar cause-and-effect relationship with a single cost driver. Referring to previous example, the single cost pool used in traditional costing is not homogenous, as machine-hours is cost driver of volume based costs, but not for purchase orders and setups. Thirdly, the cost driver causing the indirect costs should be used as the cost-allocation base to allocate these costs. (Horngren et al, 2015, 181)

In traditional costing, the focus is on products which are thought to cause costs. The basic principle in activity-based costing, on the other hand, is that products or services cause activities and activities cause costs. (Suthummanon et al, 2011, 82) The flow of production factors is illustrated in figure 9. The production of products and services require activities (refer to the concept of value chain in chapter on conceptual framework) and their outputs. Activities require resources (e.g. facilities, equipment and labour) and cause costs (e.g. rents, depreciations and salaries). Customers purchase products to satisfy his or her needs, thus generating revenues. Subtracting costs from revenue yields to earnings, either profit or loss. (Neilimo & Uusi-Rauva, 2012, 145)

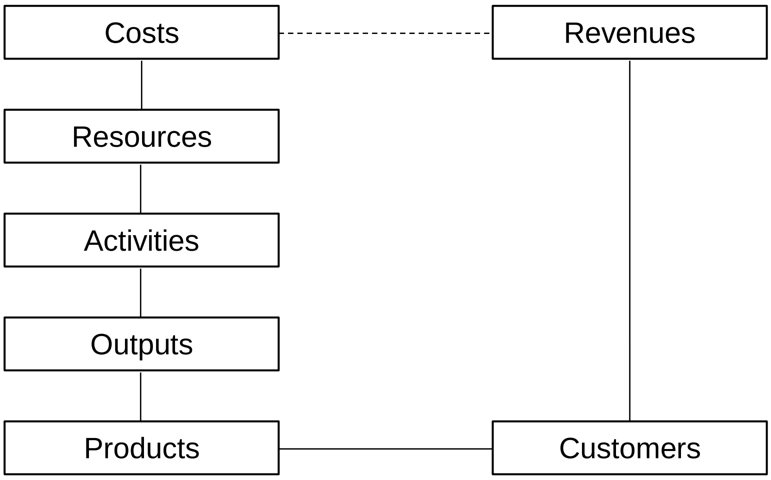

Figure 9: Flow of production factors (Neilimo & Uusi-Rauva, 2012, 145)

Overhead costs are allocated in two stages, as illustrated in figure 10. Activity-based costing assigns overhead costs to activities, rather than to departments as in traditional costing. Overhead costs are first allocated to activity cost pools using resource cost drivers that cause the activity resource consumption. At the second stage, activity costs are allocated to cost objects using activity cost drivers based on activity usage. (Drury, 2012, 253-254)

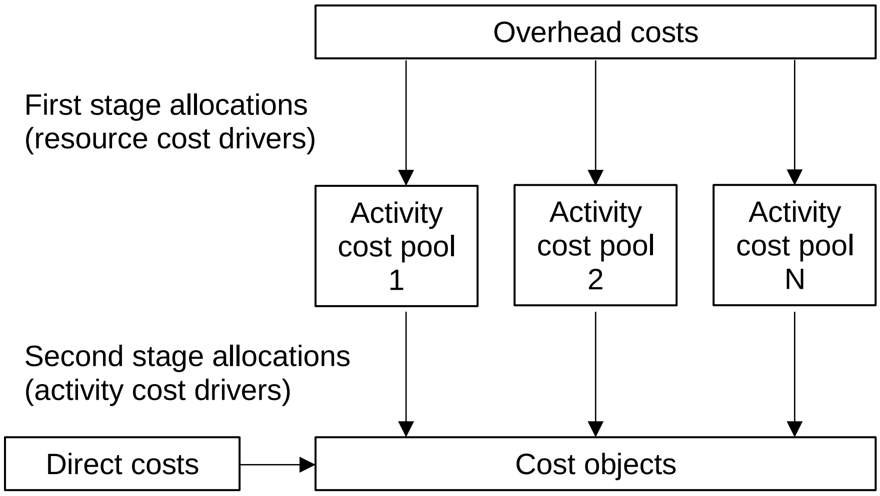

Figure 10: Overhead cost allocation in activity-based costing (Drury, 2012, 254)

Examples of resource cost drivers used in first stage allocation are use of time and resource consumption. In the second stage, activity cost drivers may be e.g. machine time, number of work-hours, number of batches and number of changes in given order. (Järvenpää, Länsiluoto, Partanen & Pellinen, 2010, 128)

5.4.3 Activities and cost drivers

Key tasks in the implementation of activity-based costing are activity analysis and the selection of cost drivers. First of all, the purpose of cost accounting influences how the activities are defined. Pricing and inventory valuation requires the definition of activities in detail. On the other hand, for strategic decision-making purposes, more general approach focusing on core activities may be sufficient. Activity differs from a cost center in that activities are linked with processes and activity means performing tasks, whereas cost centers are used for the purpose of separating costs. In newer activity-based costing models, the definition of activities relies more on processes and not on teams or other organizational boundaries. Processes are thought to be more permanent and describe better the operations. Activities defined by organizational functions, however, may work well e.g. in public sector, if processes are specific to functions and where changes in processes reflect to organizational structure. (Järvenpää et al, 2010, 132-134)

Costs behave differently according to organizational and functional level; therefore, activities are defined based on cost hierarchy. Table 13 illustrates an example of cost hierarchy. Organizational level activities are required to maintain and develop the organization as a whole. Costs are probably best handled as organizational level costs and not to be allocated to lower levels. For example, there may be no identifiable cause-and-effect relationship between the salary of CEO and products or services produced. On the other hand, product and batch level costs, such as raw materials and direct manufacturing labour are usually easy to assign to products. (Järvenpää et al, 2010, 135-137)

Table 13: Cost hierarchy (Järvenpää et al, 2010, 135)

Organizational level
Customer level
Product group level
Product level
Batch level
Unit level

In both traditional and activity-based costing methods, direct costs are traced to products or services that have caused the costs. In the allocation of indirect cost, separate cost drivers are needed. Cost drivers may be based on volume, time and degree of difficulty. (Järvenpää et al, 2010, 138-139) Different types of cost drivers are best illustrated with examples presented in table 14. (Järvenpää et al, 2010, 141)

Table 14: Examples of cost drivers (Järvenpää et al, 2010, 141)

Cost item	Volume based	Time based	Difficulty based
Purchases	Number of purchase orders	Time spent on purchase order	Type of purchase order
Inventory	Number of shipments	Time spent on offloading and shelving	Number of unusual task
Production	Number of parts; products	Machine-hours, process duration	Type of production
Setup	Number of setups	Time spent on setup	Number of unusal setups
Logistics	Number of items	Time spent on product group	Number of unusual task
Marketing	Number of products	Time spent on product category	Targeting on product category

Volume based drivers relate on the amount of activity performed, as the number of purchase orders in purchases. If the time spent on performing the activity varies by product, then using time based driver leads to more accurate allocation. For example, the machinery costs usually depend on the time the machine has been used, therefore, these costs are best allocated using machine-hours. Cost driver based on the degree of difficulty is the most accurate, but may not be usable because of lack of data by which to allocate. The degree of difficulty may be taken into account through indexing, where the average duration of activities is multiplied by constant factors, representing the difficulty of given job. Finally, the more specifically the activities are defined and the more cost drivers are used, the more complicated the activity-based costing model will be. (Järvenpää et al, 2010, 139-42)

In the case of server virtualization, activity-based costing is used to allocate costs of data center network. The activity defined is rather specific and detailed, thus providing accurate results but requiring great effort. In general, activities of an IT department may include e.g. requirements analysis, planning and design, project management, maintenance, support and administration. (Gerlach et al, 2002, 62)

5.4.4 Implementation of activity-based costing

The implementation of activity-based costing involves the following steps: (Horngren et al, 2015, 185-187)

1) Identify the cost objects
2) Identify direct costs of the cost objects
3) Select activities and cost-allocation bases to allocate indirect costs
4) Identify indirect costs of each cost-allocation base
5) Calculate indirect cost rates per each cost-allocation base
6) Calculate indirect costs for the cost object
7) Calculate total cost for the cost object by adding all direct and indirect costs

Figure 11 illustrates the principle of a real-life activity-based costing system for a IT division. Costs for PC Services and Phone are traced as direct costs and the rest of the total cost supporting multiple IT services flow through the activity-based costing system. Note that in this example, the IT division total cost of 90,3 million is accounted for. In this thesis, however, this is not the case, as the focus is on the server virtualization service. (Gerlach et al, 2002, 63)

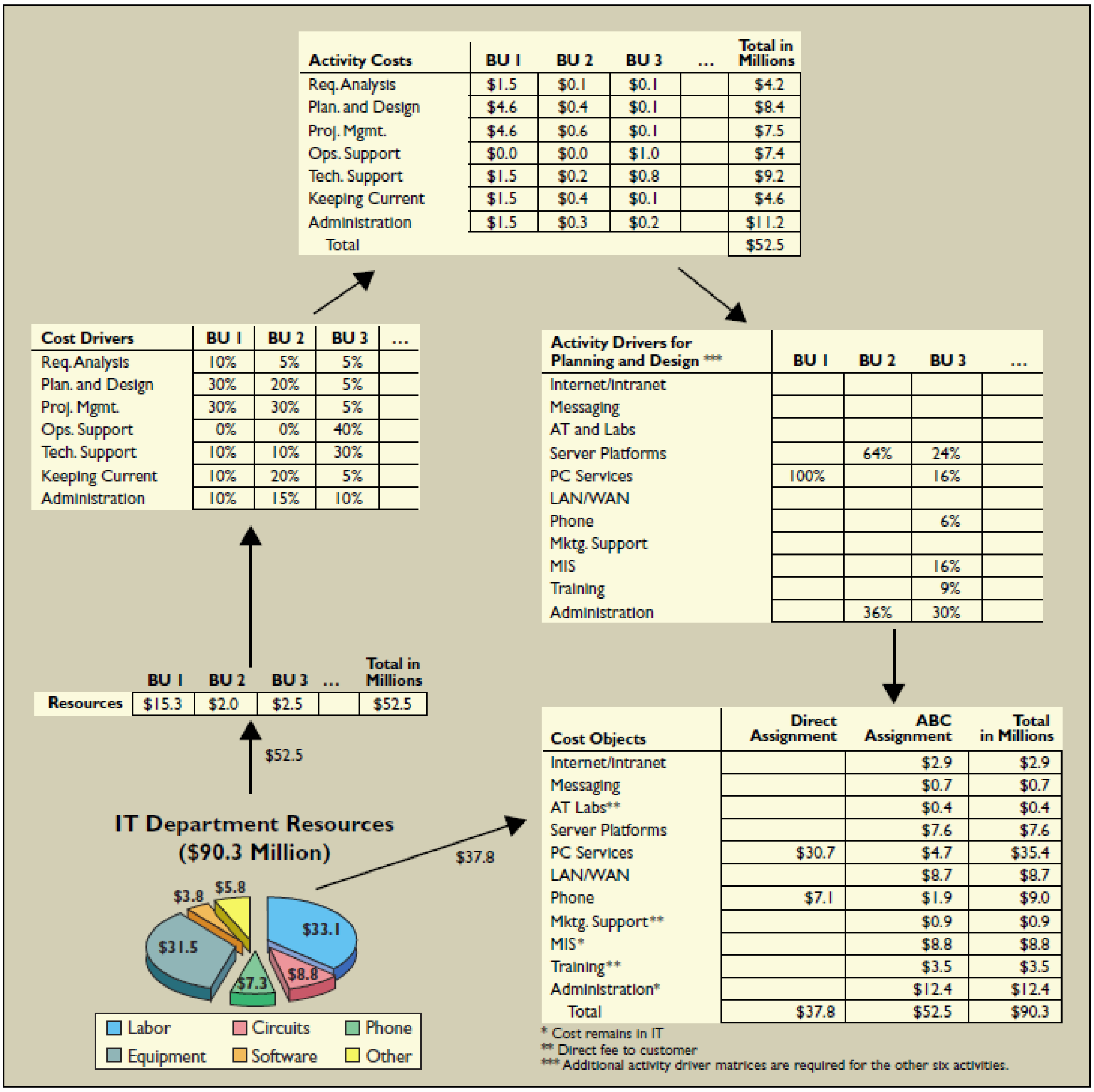

Figure 11: Example of activity-based costing (Gerlach et al, 2002, 63)

As discussed, the selection of activities and cost drivers are most critical to the success of activity-based costing. These are also highly dependent on the given accounting situation and production environment. In the case of server virtualization, activity-based costing is used to allocate data center network costs to virtual servers. Actual calculations are discussed in detail in the chapter on product costs. As will be seen, the choice of proper cost drivers is somewhat problematic, hence some degree of margin of error need to be allowed on product cost.

6 Product costs

As discussed previously, the income statement provides for valid annual operating cost data for costs registered in System Maintenance cost center. Costs for electricity, facilities and a few other minor expense items are not registered in System Maintenance cost center and need to be determined using other methods. In addition, IT equipment depreciations are neither costs of System Maintenance. All IT equipment is depreciated in four years and software in three years, regardless of actual life cycles. Since the depreciations in Metropolia level do not represent accurately the actual cost of production equipment, depreciations are determined using bottom-up method. In this case, it is actually relatively easy task and will give very accurate result, as there is only about 20 devices or device pairs of interest and their purchase prices along with other details are known. It is important to get the depreciations right, as virtual servers run on hardware along with supporting software, and with labour and connectivity, the depreciations represent most of the costs.

All investment costs in this thesis, unless otherwise noted, belong to System Maintenance cost center and the author has been responsible for the procurement of all of them. Investment costs include purchases of hardware and software, along with associated support services. These costs are well documented and therefore accurate. Deprecations are based on actual device-specific life cycles. The actual data is used whenever possible, as the main objective of this thesis is to find out the actual costs as close as possible. Using the Metropolia-level depreciations, however, would present costs too high, as life cycles are relatively long. For example, data center network devices have an average life cycle of six years, storage five years and servers either four or five years.

In the following chapters, cost data for resources used in IT service production is presented.

6.1 IT service production resources

Table 15 presents a general overview of the main resources used in IT service production. Costs of these resources are registered on different cost centers, which has implications on data availability and reliability. Cost data is sourced primarily from bookkeeping and invoicing systems. Resources and costs are discussed in detail later in this chapter.

Table 15: IT Services' resources

Resource	Cost center	Description
Labour	System Maintenance	Wages of System Maintenance team including add-on costs and overtime
Facilities	Real Estate Services	Data center and office space rent including real estate services
Electricity	Real Estate Services	Data center electricity used by IT equipment and cooling
Hardware	System Maintenance	Server, storage and network equipment including outsourced support services
Software	System Maintenance	Software licenses including outsourced support services
Connectivity	System Maintenance	Fiber and other outsourced connectivity services

6.2 Labour

Labour costs are a significant expense item, as their amount represented 48% of all operating costs of System Maintenance in 2016. However, Metropolia's time-tracking system records only the beginning and the end of a workday, and there is no measured data where the time spent falls upon. Therefore, work time spent on various activities have to be estimated and in order to obtain reasonably accurate results, a method for estimating the usage of worktime of various activities had to be developed. The estimation process consisted of the following steps, where steps 3 and 4 were repeated several times.

1) Activity analysis
2) Activity definition
3) Team member level estimations of worktime used in average week and month performed by individual team member
4) Team member and team level evaluation performed by team manager

The first step was the analysis of activities performed by System Maintenance team. At first, end user IT services produced and other IT infrastructure activities performed by

System Maintenance team were listed. Next, meaningful categorization of services and tasks had to be developed. It turned out, that the rough categories formed after analysing tasks from bottom-up were similar to service categories used in BencHEIT survey. Hence the BencHEIT survey was chosen as a basis for this task. Table 16 presents service and subservice categories used in BencHEIT survey.

Table 16: Service categories in BencHEIT survey (Metropolia, 2017c)

Infrastructure
Operational infrastructure costs
High Performance Computing
Unspecified infrastructure costs (sum.level)
Workstations, client and peripherals
Workstations
Printing and other peripherals
Unspecified peripherals (sum.level)
IT Service Desk / Helpdesk (incl. Service Point)
Data networks: LAN & WAN
Fixed networks
Wireless networks
Unspecified peripherals (sum.level)
Voice services
Telephony
Phone calls
Unspecified voice services (sum.level)
Business applications
Finance
Human resources
Facilities
Communications
Student administration systems
Research administration
Library
Teaching
Other applications
Unspecified applications
IT management, administration and information security and enterprise architecture
IT management etc.
IT Security
Unspecified IT management costs
Audio visual services
Other or unspecified services

These service categories form the basis for further analysis of the activities performed in System Maintenance team. Top-level categories are kept unchanged but second level categories are refined to allow for more detailed worktime estimation. For example, High Performance Computing is removed as there is no such service in Metropolia and none of the costs are specified as Other or unspecified. Third-level service categories were introduced in infrastructure, teaching and other business applications. Of the service categories, infrastructure is the most important concerning this thesis, as most of the costs of a virtual server are infrastructure costs.

After defining service categories, each team member estimated their worktime usage based on service categories and for an average week and month. After the individual level estimations, team manager compiled a team level spreadsheet and evaluated the total usage of worktime. Several iteration rounds were made to ensure that worktime used by each team member for various services is in proper relation to that of other team members and worktime consumed by various services are in proper relation to each other. By using the aforementioned process, it is believed that the estimations made are reasonably accurate and reliable. Similar approach based on interviews in the lack of time-tracking data is described by Gerlach et al (2002, 65) regarding labour cost drivers for a global software company, and by Ellis-Newman & Robinson (1998, 375) in a university library.

Table 17 present System Maintenance labour cost per person in 2016. Labour cost includes mandatory add-on-costs and overtime. Not included are office rents and other personnel related costs, which are handled separately as team level overhead. The use of average cost for person-workyear is not completely accurate, as different activities consume labour of different cost. However, the error is not significant and the disclosure of individual salaries is not permitted.

Table 17: System Maintenance labour costs

Wages including add-on costs and overtime	444 718 €
Person-workyears	7
Labour cost per person-workyear	63 531 €

Using the worktime estimations and labour cost per person-workyear, labour costs for each activity of System Maintenance is calculated and presented in table 18.

Table 18: System Maintenance labour cost per activity

Activity	Person-workyear	Cost	%
Infrastructure	1,52	96 567 €	21,7 %
Operational infrastructure costs	1,52	96 567 €	21,7 %
Data center facilities	0,06	3 812 €	0,9 %
Data center network	0,33	20 965 €	4,7 %
Server hardware	0,09	5 718 €	1,3 %
Storage; devices and file systems	0,18	11 436 €	2,6 %
Backup	0,13	8 259 €	1,9 %
Server virtualization	0,46	29 224 €	6,6 %
Desktop virtualization	0,15	9 530 €	2,1 %
Monitoring	0,12	7 624 €	1,7 %
Workstations, client and peripherals	0,12	7 624 €	1,7 %
Workstations	0,10	6 353 €	1,4 %
Printing and other peripherals	0,02	1 271 €	0,3 %
Helpdesk	0,65	41 295 €	9,3 %
E-mail	0,20	12 706 €	2,9 %
Cloud services	0,15	9 530 €	2,1 %
Other	0,30	19 059 €	4,3 %
Data networks: LAN & WAN	0,67	42 566 €	9,6 %
Fixed networks	0,32	20 330 €	4,6 %
Wireless networks	0,35	22 236 €	5,0 %
Voice services	0,50	31 766 €	7,1 %
Telephony	0,50	31 766 €	7,1 %
Business applications	2,71	172 169 €	38,7 %
Finance	0,15	9 530 €	2,1 %
Human resources	0,10	6 353 €	1,4 %
Facilities	0,07	4 447 €	1,0 %
Communications	0,63	40 025 €	9,0 %
Student administration systems	0,26	16 518 €	3,7 %
Library	0,01	635 €	0,1 %
Teaching	1,39	88 308 €	19,9 %
Microsoft O365	0,22	13 977 €	3,1 %
Google G Suite	0,02	1 271 €	0,3 %
Portals, eg. Oma, Peppi, Pakki	0,10	6 353 €	1,4 %
E-learning, eg. Moodle, edx	0,20	12 706 €	2,9 %
Private cloud	0,25	15 883 €	3,6 %
Student and staff projects	0,46	29 224 €	6,6 %
Network drives	0,14	8 894 €	2,0 %
Other applications	0,10	6 353 €	1,4 %
CRM, business applications	0,10	6 353 €	1,4 %
IT management	0,75	47 648 €	10,7 %
IT management, Enterprise Architecture	0,64	40 660 €	9,1 %

IT Security	0,11	6 988 €	1,6 %
Audio visual services	0,08	5 082 €	1,1 %
AV	0,08	5 082 €	1,1 %
Total	7,00	444 718 €	100 %

6.3 General overhead

Labour cost includes add-on-costs and overtime, but all other personnel related costs, which cannot be traced to cost objects in an economically feasible way, are handled as indirect overhead costs. System Maintenance overhead costs are presented in table 19.

Table 19: System Maintenance overhead costs

Real estate costs	
Espoo office, 140m^2 @ 6,62 €/month/m2	11 122 €
Helsinki office, 19m^2 @ 9,59 €/month/m2	2 187 €
Total real estate costs	13 308 €
Other personnel costs	
Training	8 741 €
Travel	5 864 €
Computers	3 500 €
Mobile devices	2 291 €
Telephone calls	2 974 €
Broadband	3 900 €
Total other personnel costs	27 270 €
Total overhead costs	40 578 €
Total overhead costs per person-year	5 797 €

Real estate costs comprise of office space rents in Helsinki and Espoo locations in 2016. Rent includes real estate services, such as cleaning and access control. Rents do not include allocations for common areas, such as restaurants, lobbies, libraries and parking lots. If the common areas were to be included, the total overhead cost per person would increase somewhat. Exact location specific common area allocations are not known, but to give an understanding of the effect, a rough estimate can be made using average rent. For a reference, total overhead costs would be 7180€ per person-year, an increase of 24%, if real estate costs were calculated using Metropolia-level average rent of 12,05 €/month/m^2.

In other personnel costs, training, travel, telephone calls and broadband are actual costs in 2016 and sourced from bookkeeping. For computers and mobile devices, costs are annualized using latest purchase prices and lifecycles in accordance with Metropolia's policies.

Using the same activities and worktime consumption as in labour costs, general overhead cost allocation to activities using person-workyear as a cost-allocation base is presented in table 20.

Table 20: System Maintenance overhead costs per activity

Activity	Person-workyear	Cost
Infrastructure	1,52	8 811 €
Operational infrastructure costs	1,52	8 811 €
Data center facilities	0,06	348 €
Data center network	0,33	1 913 €
Server hardware	0,09	522 €
Storage; devices and file systems	0,18	1 043 €
Backup	0,13	754 €
Server virtualization	0,46	2 667 €
Desktop virtualization	0,15	870 €
Monitoring	0,12	696 €
Workstations, client and peripherals	0,12	696 €
Workstations	0,10	580 €
Printing and other peripherals	0,02	116 €
Helpdesk	0,65	3 768 €
E-mail	0,20	1 159 €
Cloud services	0,15	870 €
Other	0,30	1 739 €
Data networks: LAN & WAN	0,67	3 884 €
Fixed networks	0,32	1 855 €
Wireless networks	0,35	2 029 €
Voice services	0,50	2 898 €
Telephony	0,50	2 898 €
Business applications	2,71	15 709 €
Finance	0,15	870 €
Human resources	0,10	580 €
Facilities	0,07	406 €
Communications	0,63	3 652 €
Student administration systems	0,26	1 507 €
Library	0,01	58 €

Teaching	1,39	8 058 €
Microsoft O365	0,22	1 275 €
Google G Suite	0,02	116 €
Portals, eg. Oma, Peppi, Pakki	0,10	580 €
E-learning, eg. Moodle, edx	0,20	1 159 €
Private cloud	0,25	1 449 €
Student and staff projects	0,46	2 667 €
Network drives	0,14	812 €
Other applications	0,10	580 €
CRM, business applications	0,10	580 €
IT management	0,75	4 348 €
IT management, Enterprise Architecture	0,64	3 710 €
IT Security	0,11	638 €
Audio visual services	0,08	464 €
AV	0,08	464 €
Total	7,00	40 578 €

6.4 Monitoring

Monitoring is an infrastructure activity consumed by other activities and services, and includes service level monitoring for both IT equipment and end user IT services. Main monitoring systems accounted for include commercial monitoring software and open sources tools. Monitoring activity costs comprise of depreciations and operating costs presented in table 21. Depreciations include only recently purchased Orion servers, as other servers are older and already depreciated. Operating costs include support fees for commercial software, energy and data center facilities for four rack servers, along with direct labour and general overhead. Monitoring costs are allocated onto devices and services using the number of Solarwinds Orion nodes used. Orion licences are chosen as cost allocation base, as it is the most restricting. Monitoring costs structure is presented in table 21.

Table 21: Monitoring costs

Depreciations	2 340 €
Orion servers	2 340 €
Operating costs	23 437 €
Solarwinds Orion	6 592 €
F-Secure Radar	7 375 €
Energy, 4x rack server	87 €
Data centre facilities, 8RU	1 064 €
Direct labor	7 624 €
General overhead	696 €
Total cost per year	25 777 €
Monitoring cost per node	81 €

Monitoring unit cost is computed by dividing total cost with number of nodes monitored, which is 317. Using the unit cost of 81€ per node, monitoring costs are allocated the various infrastructure activities and services by the number on consumed nodes. Table 22 presents the monitoring cost allocation.

Table 22: Monitoring cost allocation

Cost item	Nodes	Cost	%
Backup	3	244 €	1 %
Blade infrastructure	10	813 €	3 %
Campus network	99	8 046 €	31 %
Data center facilities	6	488 €	2 %
Data center network	24	1 951 €	8 %
Desktop virtualization	12	975 €	4 %
Linux servers	56	4 551 €	18 %
Other	6	488 €	2 %
Private cloud	3	244 €	1 %
Server virtualization	11	894 €	3 %
Storage	13	1 057 €	4 %
Windows servers	74	6 014 €	23 %
Total	317	25 763 €	100 %

6.5 Data center facilities

Metropolia operates two data centers, one in Helsinki and the other in Espoo. Of all the costs, only UPS, direct labour and general overhead costs are registered in System Maintenance cost center, the Financial Administration department bears all other costs. It should be noted, that data center facilities costs do not include electricity.

Major facilities expense items are rent along with power and cooling infrastructure. Real estate costs are actual location specific rents in 2016. In the case of office space, the inclusion of common areas may be justified. The data center usage, however, does not cause these costs and hence they must be excluded from data center costs.

Most of the power infrastructure related costs are known, but actual cooling infrastructure costs are uncertain. In Helsinki data center, the cost for latest investment is known. For similar investment in Espoo data center, cost is unknown and without better knowledge, the cost for Helsinki investment is used here. Power and cooling infrastructure requires yearly maintenance, but again, these costs are not known and approximate figures are presented.

As discussed above, data center total cost is not completely accurate. However, the decision is made to include all significant expense items in order to present the actual costs as close as possible. Omitting the uncertain items would present data center facilities cost unrealistically low. Table 23 presents the data center facilities costs.

Table 23: Data center facilities costs

Cost item	Helsinki	Espoo	Total	%
Real estate costs				
Data center space, m^2	44	66	110	
Storage space, m^2	18	6	24	
Rent including services, €/month/m^2	9,59 €	6,62 €		
Total real estate costs	7 135 €	5 720 €	12 855 €	34 %
Power infrastructure costs				
UPS depreciations, lifecycle 10 years	2 575 €	2 774 €		
UPS service contracts	1 685 €	1 579 €		
Maintenance	800 €	800 €		
Total power infrastructure costs	5 060 €	5 153 €	10 213 €	27 %
Cooling infrastructure costs				
Cooling depreciations, lifecycle 10 years	2 960 €	2 960 €		
Maintenance	2 000 €	2 000 €		
Total cooling infrastructure costs	4 960 €	4 960 €	9 920 €	26 %
Direct labour costs	1 525 €	2 287 €	3 812 €	10 %
Monitoring	195 €	293 €	488 €	1 %
Fixed overhead	139 €	209 €	348 €	1 %
Data center total cost	19 014 €	18 621 €	37 635 €	100 %

Data center facilities cost is allocated onto IT equipment using rack units (RU). IT equipment, including switches, routers, firewalls, servers and storage systems, are installed into racks, which stand on data center floor. IT equipment consume rack units in racks and racks consume floor space in data center. Table 24 presents data for racks and rack units.

Table 24: Data center racks

Cost item	Helsinki	Espoo	Total
Racks in use	5	8	13
Total rack units, 42U per rack	210	336	546
Used rack units	116	167	283

Table 25 presents the data center facilities unit cost. It has to be noted, that the rack units actually consumed in IT service production are used as a measure to assign data center facilities cost to IT equipment. The unit cost of total rack units is provided as a reference, but the number of total rack units in itself is irrelevant. Racks are relatively cheap and there is plenty of available floor space, so there are extra rack units available and they can be easily added. Furthermore, racks are never fully equipped, as it hinders cooling, cabling and maintenance work. Therefore, using total rack units would lead to artificially low unit cost, with no relationship to IT service production.

Table 25: Data center facilities unit cost

Cost item	RU	€/RU/y	€/RU/mo
Total rack units	546	69 €	5,74 €
Used rack units	283	133 €	11,08 €

Finally, data center facilities costs are allocated to IT equipment by using the number of rack units consumed by each device and the afore-mentioned unit cost. Data center costs per equipment type is presented in table 26.

Table 26: Data center cost per equipment type

Device	RU	Cost	%
Data center network	84	11 171 €	29,7 %
Internet routers	2	266 €	0,7 %
Console routers	2	266 €	0,7 %
Internet firewalls	4	532 €	1,4 %
Campus routers	20	2 660 €	7,1 %
DWDM	22	2 926 €	7,8 %
Data center routers	14	1 862 €	4,9 %
Data center firewalls	4	532 €	1,4 %
Data center switches	8	1 064 €	2,8 %
Load balancers	2	266 €	0,7 %
VPN	4	532 €	1,4 %
VoIP routers	2	266 €	0,7 %
Storage	46	6 117 €	16,3 %
EMC Unity storage system	18	2 394 €	6,4 %
EMC VNX storage system	24	3 192 €	8,5 %
SAN switches	4	532 €	1,4 %
Backup	31	4 123 €	11,0 %
Deduplication storage system	8	1 064 €	2,8 %
Tape library	11	1 463 €	3,9 %
Backup servers	10	1 330 €	3,5 %
Backup switches	2	266 €	0,7 %
Servers, server virtualization	21	2 793 €	7,4 %

UCS, server virtualization	19	2 527 €	6,7 %
UCS, interconnects	2	266 €	0,7 %
Servers, desktop virtualization	11	1 463 €	3,9 %
UCS, desktop virtualization	10	1 330 €	3,5 %
UCS, interconnects	1	133 €	0,4 %
Servers, private cloud	8	1 064 €	2,8 %
UCS, private cloud	7	931 €	2,5 %
UCS, interconnects	1	133 €	0,4 %
Servers, other	75	9 974 €	26,5 %
Misc. rack servers	41	5 452 €	14,5 %
HP blade	10	1 330 €	3,5 %
Email	20	2 660 €	7,1 %
UCS, misc. blades	4	532 €	1,4 %
Other	7	931 €	2,5 %
Total	283	37 635 €	100 %

6.6 Electricity

Electricity is a major expense item in data center operations. Put simply, electricity is consumed in two phases. At first, IT equipment consumes electricity delivered through uninterruptible power supply (UPS) devices and generate heat. Secondly, heat must be transferred out of the data center by the means of cooling devices, which also consume electricity. Data center efficiency is measured using PUE factor, which is determined by dividing the total electricity consumption with IT equipment electricity consumption.

The total electricity consumed in data centers is not measured, leaving roughly half of the amount under estimation, which affects the reliability of total electricity cost. The amount of electricity consumed by IT equipment is measured and is accurate. In addition, most of the IT equipment include power consumption measurement functionality at the device level. However, there is no measured or otherwise obtainable data on cooling electricity consumption and losses.

Total electricity used by IT equipment at a given point in time was determined by recording output power values of all data center UPS devices. Measurements were performed once in February 2017 and four times in different days of week in May 2017. Measured data from individual UPS devices per day were summed up and measurements of all five occasions averaged out, leading to average IT equipment power consumption of 27,3 kW. Although the period is short with limited number of data points, the results in table 27 suggest, that power consumption is practically constant with little or no effect from end user activity. This is also supported by the fact that IT infrastructure is rather stable. The small increase in power consumption from February to May can be explained with the addition of one virtualization server, whose power consumption is around 180W.

Table 27: Data center electricity consumption

UPS devices	7.2.2017	2.5.2017	12.5.2017	18.5.2017	24.5.2017	Average
Espoo data center						
UPS #1	12,9 kW	13,0 kW	13,3 kW	13,1 kW	13,2 kW	
UPS #2	1,5 kW	1,5 kW	1,5 kW	1,5 kW	1,5 kW	
UPS #3	1,5 kW	1,5 kW	1,5 kW	1,5 kW	1,5 kW	
Espoo total	15,9 kW	16,0 kW	16,3 kW	16,1 kW	16,2 kW	16,1 kW
Helsinki data center						
UPS #1	10,3 kW	10,5 kW	10,4 kW	10,4 kW	10,6 kW	
UPS #2	0,8 kW	0,8 kW	0,8 kW	0,8 kW	0,8 kW	
Helsinki total	11,1 kW	11,3 kW	11,2 kW	11,2 kW	11,4 kW	11,2 kW
Total						27,3 kW

The data center facilities are not originally designed for data center usage, which among other challenges, translates into energy inefficiencies. Cooling is carried out traditionally by blowing cold air underneath the floor and hot air is drawn out at the top of the room. A cooling system using this principle, where the whole data center room space is cooled instead of cooling the individual isolated racks, is not the most energy efficient solution. Therefore, it is assumed that PUE factor cannot be under 2 and in no circumstances anywhere near 1. PUE factor of 2 means, that the data center total energy usage is twice that of consumed by IT equipment. In other words, if IT equipment consumes 10kW of energy, losing another 10kW into cooling computes to PUE factor (10kW + 10kW) / 10kW = 2. Cooling losses are best guesses without any actual data and therefore, obtained PUE factors are only rough approximates. Table 28 present the calculated PUE factors for Helsinki and Espoo data center.

Table 28: Data center PUE factors

	Helsinki	Espoo	Total
IT equipment electricity (UPS output)	11,2 kW	16,1 kW	27,3 kW
Losses			
UPS lossess, % of output	10 %	3,70 %	
UPS lossess	1,1 kW	0,6 kW	1,7 kW
Cooling losses, % of output and UPS lossess	150 %	100 %	
Cooling losses	18,5 kW	16,7 kW	35,2 kW
Total losses	19,7 kW	17,3 kW	37,0 kW
Total facility electricity	30,9 kW	33,4 kW	64,3 kW
Data center PUE	2,75	2,07	2,35

After estimating total electricity consumption and location specific PUE factor, electricity consumption and cost is determined by each device used in IT service production. At first, price of electricity needs to be computed. Electricity price comprises of energy and transfer prices, monthly basic and other fees, and tax on electricity. As with all other costs in this thesis, VAT is not included. In this thesis, price of electricity includes only the prices for energy and transfer and tax. All other fees are excluded.

For electrical energy, Metropolia has a single supplier with a price of 6,16 c/kWh. For energy transfer, Helsinki data center is supplied by local electricity company Helen Sähköverkko Oy and similarly Caruna Espoo Oy for Espoo data center. Transfer price depends on location and on the time of day and month of the year, where different suppliers have a little different pricing model. In this thesis, transfer price is computed by weighting winter day time price and other time price with their respective number of hours in a year. The transfer price is therefore average and it is not based on actual monthly data center electricity consumption. As stated before, the total electricity consumption is not measured, and therefore obtaining a completely accurate consumption and cost of it is not possible. In addition, data center electricity consumption seem to be rather constant as servers run 24/7 and with little effect to load and energy consumption from end user activity, thus using average transfer price is believed to reflect rather well the actual energy consumption pattern. Table 29 presents transfer price for Helsinki data center and table 30 for Espoo data center.

Table 29: Electricity transfer price for Helsinki data center

Helsinki data center					
	Price	Win-ter/h	Other/h	%	Transfer
Winter day time[1]	1,140 c/kWh	840		9,59 %	0,109 c/kWh
Other time	0,610 c/kWh		7920	90,41 %	0,552 c/kWh
Tax	2,253 c/kWh				2,253 c/kWh
Total					2,914 c/kWh

1) December-February Monday-Friday 7-21

Table 30: Electricity transfer price for Espoo data center

Espoo data center					
	Price	Winter/h	Other/h	%	Transfer
Winter day time[1]	1,590 c/kWh	1800		20,55 %	0,327 c/kWh
Other time	0,750 c/kWh		6960	79,45 %	0,596 c/kWh
Tax	2,253 c/kWh				2,253 c/kWh
Total					3,176 c/kWh

1) November-March Monday-Saturday 7-22

Using the determined electrical energy and transfer prices, total cost for electricity is computed and presented in table 31.

Table 31: Data center electricity costs

	Helsinki	Espoo	Total
Total facility electricity, kW	30,9 kW	33,4 kW	64,3 kW
Total facility electricity, kWh	270 772 kWh	292 509 kWh	563 280 kWh
Price of electrical energy	6,160 c/kWh	6,160 c/kWh	
Price of energy transfer	2,914 c/kWh	3,176 c/kWh	
Price of electricity	9,074 c/kWh	9,336 c/kWh	
Total data center electricity cost	24 570 €	27 309 €	51 878 €

Finally, total electricity consumed, and cost of it, is allocated to IT equipment used in IT service production. IT equipment electricity consumption is determined primarily by reading power usage counters at the device level. If this functionality is not available, a typical power consumption stated in data sheet is used. In some cases, reliable source is not available and power consumption is estimated based on known consumption of similar devices. Regarding rack servers, measured value is used when available and an average of these is used for the rest. 82% of the total electricity consumption is obtained from device level measurements and 9% form data sheets. The remaining 9% is estimated, including some 3% of total consumption allocated to other devices to reach the measured amount of power consumption. As 91% of the consumption is sourced either from measurements or data sheets, it is believed that the allocation is reasonably accurate and sufficient for the purposes of this thesis. It has to be noted, that the reliability of the internal device level power usage measurement functionality is not verified. If 100% accurate and reliable power consumption figures are needed, external purpose-built power meters have to be used.

Device level power consumption measurements were performed once in a week in May 2017 and the average of these measurements is used as a consumption figure. This was chosen as a measurement schedule, as a preliminary research had shown, that time of the day or day of the week didn’t appear to have much effect on power consumption. For a reference, the power consumption measurements data for Cisco UCS blade and rack server infrastructure is presented in table 32. Measured reading represents the average power consumption of that point in time. Server virtualization runs on servers named esxi1 through esxi6.

One might expect the load on servers generated by end user activities and therefore the server power consumption to vary, but as can be seen from the data, most of the samples are close to the average and only 8 of the 116 samples have a deviation of more than ± 10% from average. In other devices, the deviations from average are even smaller or non-existent, meaning that variations in load do not cause any meaningful difference in energy consumption.

Table 32: Cisco UCS server infrastructure power consumption (watt)

Chassis #	Server #	Server name	2.5.2017	12.5.2017	18.5.2017	24.5.2017	Average
Espoo data center							
Chassis 1	Server 1	mysqldev1	94	89	100	77	90
	Server 3	esxi5	188	196	186	184	189
	Server 4	esxi6	191	175	177	186	182
	Server 5	esxi3	188	184	189	186	187
Chassis 2	Server 1	esxi1	222	206	189	191	202
	Server 2	esxi2	198	200	189	192	195
	Server 5	educ-esxi2	94	100	85	88	92
	Server 6	educ-esxi1	104	103	92	96	99
Chassis 3	Server 1	educ-esxi4	90	91	92	90	91
	Server 2	educ-esxi3	89	90	88	90	89
	Server 7	esxi4	198	200	193	198	197
Interconnect A		PSU1	174	174	173	171	173
		PSU2	154	154	154	154	154
Interconnect B		PSU1	158	158	160	157	158
		PSU2	168	169	169	169	169
Helsinki data center							
Chassis 2	Server 4	ns	93	74	74	81	81
	Server 5	esxi1	171	170	164	143	162
	Server 6	esxi2	152	166	138	166	156
Chassis 3	Server 5	esxi3	149	150	173	153	156
	Server 6	esxi4	169	135	158	159	155
Rack	Server 1	view-esxi1	248	243	256	252	250
	Server 2	view-esxi2	185	193	187	173	185
	Server 3	view-esxi3	185	193	176	184	185
	Server 4	view-esxi4	199	183	186	189	189
	Server 5	view-esxi5	201	196	191	193	195
Interconnect A		PSU1	156	156	156	156	156
		PSU2	161	160	160	160	160
Interconnect B		PSU1	172	171	171	171	171
		PSU2	169	168	168	168	168

In order to obtain the final power consumption per device, the device level power consumption is multiplied with data center specific PUE factor to account for cooling and other losses. The total consumption including losses is multiplied with data center specific electricity price in order to obtain the electricity cost for each device. Table 33 presents the device level total power consumption and cost, including losses.

Table 33: Data center electricity costs per device

Device	Source	kW	kWh	Cost	%
Data center network		23,9 kW	209 442 kWh	19 279 €	37,2 %
Internet routers	Data sheet	0,4 kW	3 803 kWh	350 €	0,7 %
Console routers	Data sheet	0,2 kW	1 479 kWh	136 €	0,3 %
Internet firewalls	Data sheet	0,8 kW	6 761 kWh	622 €	1,2 %
Campus routers	Measurement	10,3 kW	90 475 kWh	8 328 €	16,1 %
DWDM	Estimate	0,7 kW	6 339 kWh	583 €	1,1 %
Data center routers	Measurement	1,7 kW	15 213 kWh	1 400 €	2,7 %
Data center firewalls	Data sheet	1,5 kW	13 523 kWh	1 245 €	2,4 %
Data center switches	Measurement	5,8 kW	50 720 kWh	4 669 €	9,0 %
Load balancers	Data sheet	0,7 kW	6 127 kWh	564 €	1,1 %
VPN	Data sheet	1,5 kW	13 523 kWh	1 245 €	2,4 %
VoIP routers	Data sheet	0,2 kW	1 479 kWh	136 €	0,3 %
Storage		9,1 kW	79 479 kWh	7 281 €	14,1 %
EMC Unity storage system	Measurement	2,4 kW	21 157 kWh	1 975 €	3,8 %
EMC VNX storage system	Measurement	5,5 kW	48 180 kWh	4 372 €	8,6 %
Data center SAN switches	Measurement	1,2 kW	10 142 kWh	934 €	1,8 %
Backup		3,8 kW	33 065 kWh	3 087 €	5,9 %
Deduplication storage system	Estimate	2,1 kW	18 168 kWh	1 696 €	3,2 %
Tape library	Data sheet	0,2 kW	1 817 kWh	170 €	0,3 %
Backup servers	Estimate	1,0 kW	9 084 kWh	848 €	1,6 %
Backup switches	Measurement	0,5 kW	3 996 kWh	373 €	0,7 %
Servers, server virtualization		5,8 kW	50 907 kWh	4 686 €	9,0 %
UCS, server virtualization	Measurement	4,2 kW	36 710 kWh	3 379 €	6,5 %
UCS, interconnects	Measurement	1,6 kW	14 196 kWh	1 307 €	2,5 %
Servers, desktop virtualization		3,9 kW	33 900 kWh	3 076 €	6,0 %
UCS, desktop virtualization	Measurement	2,8 kW	24 447 kWh	2 218 €	4,3 %
UCS, interconnects	Measurement	1,1 kW	9 454 kWh	858 €	1,7 %
Servers, private cloud		1,1 kW	9 362 kWh	874 €	1,7 %
UCS, private cloud	Measurement	0,8 kW	6 751 kWh	630 €	1,2 %
UCS, interconnects	Measurement	0,3 kW	2 611 kWh	244 €	0,5 %
Servers, other		14,6 kW	127 636 kWh	11 761 €	22,7 %
Misc. rack servers	Measurement	5,8 kW	50 615 kWh	4 659 €	9,0 %
HP blade	Measurement	1,5 kW	12 909 kWh	1 205 €	2,3 %
Email	Measurement	6,7 kW	59 044 kWh	5 435 €	10,5 %
UCS, misc. blades	Measurement	0,4 kW	3 655 kWh	332 €	0,6 %
UCS, interconnects	Measurement	0,2 kW	1 414 kWh	130 €	0,3 %
Other	Estimate	2,2 kW	19 077 kWh	1 756 €	3,4 %
Total		64,3 kW	562 868 kWh	51 800 €	100 %

6.7 Data center network

Data center network is the most significant expense item in server virtualization costs, representing roughly half of the total cost of virtual server. Data center network activity is also the most complicated activity to account for, as it comprises of many sub-functions, whose cause-and-effect relationship with the final cost object, a virtual server, is difficult to determine. In many cases, even if there is a causal connection between virtual server and its usage of a certain network device's resources, there is no practical, i.e. cost-effective way to measure the resource usage. Data center costs are indirect and in order to achieve as accurate cost allocation as possible with available data, activity based costing is chosen as a cost accounting method. In this case, the single most important factor affecting the accuracy of ABC are the cost drivers.

6.7.1 Data center network total costs

Even though data center network costs are indirect in relation to cost object, the data center activity itself comprises of many direct costs. As a first item, the investment and operating costs of data center network devices are presented in table 34 and table 35.

Table 34: Data center network equipment costs

	DWDM	Internet routers	Internet firewalls	Campus routers	Load bal-ancers
Depreciations	23 419 €	3 354 €	35 134 €	20 710 €	31 745 €
Life cycle, years	9	5	6	5	5
Investment costs	210 771 €	16 768 €	210 801 €	103 550 €	158 725 €
Operating costs	3 509 €	616 €	1 154 €	10 988 €	830 €
Energy	583 €	350 €	622 €	8 328 €	564 €
Data center facilities	2 926 €	266 €	532 €	2 660 €	266 €
Total cost per year	26 928 €	3 970 €	36 288 €	31 698 €	32 575 €

Table 35: Data center network equipment costs, continued

	Data center firewalls	Data center routers	Data center switches	VPN
Depreciations	16 085 €	6 114 €	19 320 €	7 847 €
Life cycle, years	7	6	6	8
Investment costs	112 596 €	36 684 €	115 918 €	62 775 €
Operating costs	1 777 €	3 262 €	5 733 €	1 777 €
Energy	1 245 €	1 400 €	4 669 €	1 245 €
Data center facilities	532 €	1 862 €	1 064 €	532 €
Total cost per year	17 862 €	9 376 €	25 052 €	9 624 €

In addition to hardware and software costs, there are a few other cost categories associated with the data center network acitivity. The costs for direct labour, general overhead and monitoring are assigned as discussed previously. Fibers and connectivity includes charges for data center interconnect fibers, secondary internet connection fiber and data center related share of Funet basic charge. The Funet basic charge covers the cost of primay internet connection. The data center network costs are presented in table 36.

Table 36: Data center network total cost

Cost item	Labour	Outsourced	Depreciation	Energy	Facilities	Internal	Total	%
Direct labour	20 965 €						20 965 €	7 %
General overhead						1 913 €	1 913 €	1 %
Monitoring						1 952 €	1 952 €	1 %
Fibers and connectivity		67 211 €					67 211 €	24 %
DWDM			23 419 €	583 €	2 926 €		26 928 €	9 %
Internet routers			3 354 €	350 €	266 €		3 970 €	1 %
Internet firewalls			35 134 €	622 €	532 €		36 288 €	13 %
Campus routers			20 710 €	8 328 €	2 660 €		31 698 €	11 %
Load balancers			31 745 €	564 €	266 €		32 575 €	11 %
Data center firewalls			16 085 €	1 245 €	532 €		17 862 €	6 %
Data center routers			6 114 €	1 400 €	1 862 €		9 376 €	3 %
Data center switches			19 320 €	4 669 €	1 064 €		25 052 €	9 %
VPN			7 847 €	1 245 €	532 €		9 624 €	3 %
Total	20 965 €	67 211 €	163 727 €	19 007 €	10 639 €	3 865 €	285 413 €	100 %
%	7 %	24 %	57 %	7 %	4 %	1 %	100 %	

6.7.2 Data center network cost drivers

Next, the data center network total cost has to be allocated to other data center activities consuming the network activity. Table 37 present the chosen cost drivers along with short explanation of cause-and-effect relationship. Most of the costs are allocated using either data center logical host or all logical hosts. As the terms implies, the former includes hosts in data center environment and latter also end user devices. The term logical host refers to both physical and virtual hosts.

Table 37: Data center network cost drivers

Data center network activity	Cost driver	Cause-and-Effect relationship
Data center network labour	DC logical hosts	Configuration tasks are required when a new server is installed
General overhead	DC logical hosts	Overhead falls upon all logical hosts
Fibers and connectivity	DC logical hosts	Fibers are needed for DC interconnect and internet access
DWDM	DC logical hosts	DWDM is needed for interconnecting the data centers
Internet routers	All logical hosts	Internet routers are needed for routing all logical hosts' traffic
Internet firewalls	All logical hosts	Internet firewalls are needed for protecting all logical hosts
Campus routers	All logical hosts	Campus routers are needed for routing all logical hosts' traffic
Load balancers	Load balancer VIP's	Load balancer Virtual IP's map to services being load balanced
Data center firewalls	DC logical hosts	DC firewalls are needed for protecting DC logical hosts
Data center routers	DC logical hosts	DC routers are needed for routing DC logical hosts' traffic
Data center switches	DC switch ports	DC switches are needed for connecting physical devices
VPN	All logical hosts	Remote access for both system maintenance and end users
Monitoring	DC logical hosts	All logical hosts used in service production are monitored

In the following, the cost drivers are discussed. First of all, **all logical hosts** refer to all infrastructure or end user devices, who frequently access both internet and IT services provided by Metropolia. Categories and number of hosts is presented in table 38. The absolute number of all hosts is impossible to measure, as the number of hosts accessing network is never constant. End user devices, both user owned and those provided Metropolia's IT services, come and go with users and hence the amount changes daily. In addition, finding out the exact number is not even necessary. As can be seen from the ratios, vast majority of the hosts are in any case end user devices. The number of work-stations and end user owned devices (BYOD) are obtained from BencHEIT 2016 survey (Metropolia, 2017c). Excluded are certain device categories, e.g. WLAN access points

(415 units), IP phones (228) and network printers (201), which are for internal use and do not require internet access or consume any notable amount of data center resources.

Table 38: All logical hosts

All logical hosts	Count	%
Server virtualization	285	3 %
Desktop virtualization	155	2 %
Private cloud	146	2 %
Miscellaneous rack servers	22	0 %
Email servers	5	0 %
Miscellaneous blade servers	4	0 %
End user devices	8 046	93 %
Workstations	5 846	
BYOD	2 200	
Total	8 662	100 %

All logical hosts are used to allocate costs of those named data center network infrastructure functions, which are needed by all hosts accessing public and private IT services. These common to all network infrastructure functions include internet routing and firewalling, campus routing and remote access VPN. As always, this cost driver is also a compromise, where there are some data available and some more accurate data that could be obtained, but with a cost. In theory, the allocation of e.g. internet access cost would be more precise by taking into consideration also the number of users or the amount of data each user transferred in a given period. However, then there would be a mix of users, devices and possibly traffic volumes. Some method of weighting should be used to take into account, that servers and services need more attention and resources than end users. This would add unnecessary cost and complexity, as using the average device counts assigns most of the costs to the categories that link to the root cause for these costs, namely the end users need to access IT services to perform their daily tasks.

Subtracting end user devices from all hosts leaves out **data center logical hosts**, as presented in table 39. These include virtual hosts (server and desktop virtualization, private cloud) and physical servers (misc. rack, email, misc. blade).

Table 39: Data center logical hosts

Data center logical hosts	Count	%
Server virtualization	285	46 %
Desktop virtualization	155	25 %
Private cloud	146	24 %
Miscellaneous rack servers	22	4 %
Email servers	5	1 %
Miscellaneous blade servers	4	1 %
Total	616	100 %

Many of the data center network activity costs are allocated using data center logical hosts. Many configuration tasks are triggered and resource usage increased, when a new server is added, so the number of hosts is a natural vehicle for most cost assignment. Logical hosts translate to IP addresses, which is one of the primary bases on which network equipment function. Routing is based on IP, so using the number of hosts being routed makes most sense to allocate routing costs. Similarly, monitoring costs are correctly allocated using the number of logical host being monitored. Regarding firewalls, the number of hosts is the only useful and available indicator. Daily operations of a firewall include rule creation and modification along with log analysis. Firewall policy can be constructed in many ways and sometimes creating more rules than a bare minimum makes the policy more understandable, hence the number of rules is not meaningful indicator to assign costs. For overhead, fiber and DWDM costs, there is no better indicator available as these activities fall upon all hosts in data center environment. Load balancers and data center switches have their own specific indicators.

The number of hosts is determined once a week during a four-week time in May 2017, and once in February for virtual servers, and averages are used here. For a reference, the data for virtual hosts is presented in table 40. The numbers represent the amounts of powered on, or actively used, hosts. Powered off hosts are stored but not used for various reasons, and are excluded, as they do not consume network resources.

Table 40: Number of virtual machines

	8.2.2017	2.5.2017	12.5.2017	18.5.2017	24.5.2017	Average
Server virtualization	280	302	280	280	281	285
Desktop virtualization		166	153	156	146	155
Private cloud		203	207	93	79	146

Load balancing costs are accurately allocated using **load balancer VIP's**, as every specific service being load balanced has its own virtual IP. Table 41 presents the distribution of VIP's.

Table 41: Load balancer VIP's

Load balancer VIP's	Count	%
Server virtualization	45	79 %
Desktop virtualization	1	2 %
Private cloud	1	2 %
Miscellaneous rack servers	3	5 %
Email servers	6	11 %
Miscellaneous blade servers	1	2 %
Total	57	100 %

Switches provide physical connectivity; hence the number of **data center switch ports** is used as a measure to allocate switching costs. Switch port is not a perfect indicator, as a single port or port-channel can connect individual server with single MAC address or a blade system with thousands of MAC addresses. Switches operate on MAC level and therefore using MAC addresses would remedy the problem associated with the device type connected on each port. Once again, data for achieving this level of precision is not available, as MAC addresses are not recorded or mapped to services. Data center switch port distribution is presented in table 42.

Table 42: Data center switch ports

Data center switch ports	Count	%
Server virtualization	6	6 %
Desktop virtualization	4	4 %
Private cloud	2	2 %
Miscellaneous rack servers	53	52 %
Email servers	25	25 %
Miscellaneous blade servers	4	4 %
End user devices	8	8 %
Total	102	100 %

6.7.3 Data center network cost allocation

Table 43 presents the previously discussed cost drivers percentages applied to data center network activities.

Table 43: Data center network activity consumption

Data center network activity	Virtual servers	Virtual desktops	Private cloud	Misc. rack servers	Email servers	Misc. blade servers	End user devices	Total
Data center network labour	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
Fixed overhead	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
Fibers and connectivity	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
DWDM	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
Internet routers	3 %	2 %	2 %	0 %	0 %	0 %	93 %	100 %
Internet firewalls	3 %	2 %	2 %	0 %	0 %	0 %	93 %	100 %
Campus routers	3 %	2 %	2 %	0 %	0 %	0 %	93 %	100 %
Load balancers	79 %	2 %	2 %	5 %	11 %	2 %	0 %	100 %
Data center firewalls	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
Data center routers	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
Data center switches	6 %	4 %	2 %	52 %	25 %	4 %	8 %	100 %
VPN	3 %	2 %	2 %	0 %	0 %	0 %	93 %	100 %
Monitoring	46 %	25 %	24 %	4 %	1 %	1 %	0 %	100 %
Total	34 %	14 %	13 %	7 %	4 %	1 %	27 %	

Finally, table 44 present the data center network total costs assignment to data center network activities using the previously discussed cost drivers.

Table 44: Data center network activity costs

Data center network activity	Virtual servers	Virtual desktops	Private cloud	Misc. rack servers	Email servers	Misc. blade servers	End user devices	Total
Data center network labour	9 681 €	5 281 €	4 949 €	748 €	170 €	136 €	0 €	20 965 €
Fixed overhead	883 €	482 €	452 €	68 €	16 €	12 €	0 €	1 913 €
Fibers and connectivity	31 035 €	16 929 €	15 866 €	2 399 €	545 €	436 €	0 €	67 211 €
DWDM	12 434 €	6 783 €	6 357 €	961 €	218 €	175 €	0 €	26 928 €
Internet routers	130 €	71 €	67 €	10 €	2 €	2 €	3 687 €	3 970 €
Internet firewalls	1 192 €	650 €	610 €	92 €	21 €	17 €	33 706 €	36 288 €
Campus routers	1 041 €	568 €	532 €	81 €	18 €	15 €	29 443 €	31 698 €
Load balancers	25 717 €	571 €	571 €	1 714 €	3 429 €	571 €	0 €	32 575 €
Data center firewalls	8 248 €	4 499 €	4 217 €	638 €	145 €	116 €	0 €	17 862 €
Data center routers	4 329 €	2 362 €	2 213 €	335 €	76 €	61 €	0 €	9 376 €
Data center switches	1 474 €	982 €	491 €	13 017 €	6 140 €	982 €	1 965 €	25 052 €
VPN	316 €	172 €	162 €	24 €	6 €	4 €	8 939 €	9 624 €
Monitoring	901 €	492 €	461 €	70 €	16 €	13 €	0 €	1 952 €
Total	97 382 €	39 843 €	36 948 €	20 158 €	10 802 €	2 540 €	77 739 €	285 413 €
Total %	34 %	14 %	13 %	7 %	4 %	1 %	27 %	100 %

Table 45 presents data center network activity unit costs per host per infrastructure service category.

Table 45: Data center network cost per service category

Cost item	Cost	Hosts	Unit cost
Server virtualization	97 382 €	285	342 €
Desktop virtualization	39 843 €	155	257 €
Private cloud	36 948 €	146	254 €
Miscellaneous rack servers	20 158 €	22	916 €
Email servers	10 802 €	5	2 160 €
Miscellaneous blade servers	2 540 €	4	635 €
End user devices	77 739 €	8 046	10 €
Total	285 413 €	8 662	

6.7.4 Validity and reliability of indirect cost allocation

The number of data center logical hosts themselves are accurate, but it is somewhat problematic as what hosts to include and how it should be done. Self-evidently, servers are to be included, but desktop virtualization and private cloud require consideration. Virtual desktop, or workstation, belong to the category of end user computing as physical workstations do. Unlike the standalone physical workstations in offices and classrooms, virtual desktops are provided by desktop virtualization system running on data center infrastructure. The same applies to private cloud, where the hosts are technically servers running server operating system, but they are being used by single or a group of few students, and therefore are in practice comparable to workstations. As both desktop virtualization and private cloud consume data center resources, they must be somehow included to account for the cost of these resources. In this thesis, the decision is made to include all of these hosts on one-to-one basis. In theory, as a single virtual server serves much more clients than a single virtual desktop or private cloud host does, virtual servers should be weighted more heavily than the others should.

The presented data center logical host distribution may be somewhat open to discussion but in overall, the result is roughly in line with the actual data center operations. As the ratios show, both servers and end user computing represent roughly one-half of the total cost. For sure, server virtualization is a critical component and is consumed by nearly all of the end user IT services. It should bear much of the cost, but not all, as there are also other services causing the infrastructure costs. In addition, many other approaches were tried to resolve the cost allocation problem. For example, costs were allocated using the number of physical servers, server rack units, server IP addresses and server energy usage, but these drivers would allocate even less cost to server virtualization. In the end, the discussed method was chosen, as it is believed to allocate a fair share of the costs to server virtualization. If more accurate result is needed or the number of end user virtual hosts increases significantly, and thereby lowers the share of server virtualization, then a more sophisticated cost assignment method with proper weighting should be developed.

Most of the data center network costs regarding network devices would be allocated more accurately using actual traffic volumes, but traffic volume data is not recorded. It would be quite a burden to record traffic volumes and map those volumes to services for that data to be useful in cost assignment.

The previously discussed indicators also reveal why activity-based costing provides more accurate results, when compared to traditional costing methods with arbitrary volume-based cost drivers. Without ABC, one might allocate data center network costs using number of logical hosts, as this indicator is easy to obtain and in most cases, reasonably accurate. In this case, server virtualization would be allocated 46% of all costs. However, as can be seen by examining the costs driver data, 46% of costs is not a fair share for server virtualization in all functions. Regarding all hosts and data center switch ports, server virtualization is responsible for only 3% and 6% of total costs, respectively. On the other hand, virtual servers are accounted for 79% of load balancing costs. Server virtualization will bear 34% of the data center network costs, not 46%.

As discussed earlier, the handling of end user computing is somewhat problematic. One might argue that the 34% share of data center network cost for server virtualization is too low. More accurate allocation would require weighting all end user related devices in proper relation to servers in all logical hosts. This is not in the scope of this thesis, but a simple simulation can be made by dividing the number end user device, desktop virtualization and private cloud hosts by 10 in all logical hosts and data center logical hosts resource drivers. Note that load balancer VIP's and data center switch ports do not change with number of logical hosts. The number of end user related hosts drops to one tenth and as a consequence, the relative share of server virtualization increases from 3% to 25% in all logical hosts and from 46% to 82% in data center logical hosts. This in turn increases the server virtualization's share of data center network costs from 34% to 59%. Finally, unit cost of a single virtual server increases 32%. Or, if divided by 20, the unit cost will increase by 40%. Of course, the use of such arbitrary numbers is not feasible practice, as there is no causal connection to resource usage causing the costs. As a conclusion, end user computing may be given less share with proper weighting, but a reasonable cost assignment scheme needs to be developed.

6.8 Unified Computing System

Almost all of the IT services in Metropolia run on Cisco Unified Computing System (UCS), with email being the only major exception. Main building blocks of an UCS system are interconnect switches, blade server chassis and fabric extenders comprising the UCS infrastructure, and blade and rack servers providing for the actual computing. UCS is used mainly as a virtualization platform, there are only a few non-virtualization servers attached. UCS servers represent 44% of all physical server, as illustrated in table 46.

Table 46: Physical servers

	Count	%
Email	5	10 %
HP blades	1	2 %
Misc. rack servers	22	44 %
UCS, desktop virtualization	5	10 %
UCS, misc. blades	3	6 %
UCS, private cloud	4	8 %
UCS, server virtualization	10	20 %
Total	50	100 %

Table 47 presents the UCS infrastructure investment and operating costs. Direct labour and general overhead costs are determined for all physical servers, of which 44% is allocated to UCS infrastructure. UCS infrastructure cost is a fixed cost and fall upon all UCS servers. Note on monitoring: The infrastructure components are monitored separately from servers, therefore monitoring costs appear twice in UCS costs. The same applies to energy, as interconnect switches and chassis' power usage is separate from that of servers.

Table 47: UCS server infrastructure total cost

Depreciation	18 747 €
Life cycle, years	5
Investment costs	93 734 €
Operating costs	10 619 €
Energy	2 539 €
Data center facilities, 34RU	4 522 €
Direct labour, 44% of server HW	2 516 €
Monitoring	813 €
General overhead, 44% of server HW	230 €
UCS infrastructure total cost	29 365 €

From total UCS infrastructure cost, a unit cost per server is calculated and presented in table 48.

Table 48: UCS server infrastructure unit cost

	Servers
Server virtualization	10
Desktop virtualization	5
Private cloud	4
Other	3
Total	22
UCS infrastructure cost per server	1 335 €

Finally, the cost of actual servers is added and total cost of server virtualization servers is presented in table 49.

Table 49: Virtualization server cost

Depreciation	23 550 €
Life cycle, years	5
Investment costs	117 750 €
Operating costs	17 622 €
Energy	3 379 €
Blade infrastructure costs	13 348 €
Monitoring	894 €
Server virtualization servers total cost	41 172 €
Virtualization server unit cost	4 117 €

Server usage, investment and operating costs are all known, so the presented cost is as accurate as it can be.

6.9 Storage systems

Storage systems, as the name implies, are used for storing data. In this case, two separate storage systems in two different data centers are used to provide file and block level storage services. File storage provides for end user home directories and network shares. Block storage is in the interest of this thesis and is used for server boot and data disks. All UCS servers have no local disk space, their boot and data disks reside in storage arrays.

First up, the storage infrastructure total cost is determined. Infrastructure cost is a fixed cost and common to all of the disk space. Storage infrastructure comprises of SAN switches and storage system chassis. Table 50 present the total cost for storage infrastructure.

Table 50: Storage infrastructure total cost

EMC Unity storage system chassis	
Depreciation	17 028 €
Life cycle, years	5
Investment costs	85 138 €
Operating costs	4 369 €
Energy	1 975 €
Data center facilities	2 394 €
Unity chassis total cost	21 397 €
EMC VNX storage system chassis	
Depreciation	17 000 €
Life cycle, years	5
Investment costs	85 000 €
Operating costs	7 564 €
Energy	4 372 €
Data center facilities	3 192 €
VNX chassis total cost	24 564 €
Data center SAN switches	
Depreciation	2 825 €
Life cycle, years	6
Investment costs	16 951 €
Operating costs	1 466 €
Energy	934
Data center facilities	532 €
SAN switches total cost	4 291
Direct labour	11 436 €
Monitoring	1 057 €
Fixed overhead	1 043 €
Storage infrastructure total cost	63 787 €

Next, the storage infrastructure unit cost is computed and presented in table 51. Although storage systems provide capacity measured in bytes, costs incur in practice with number of disks. Different types of disks have also different performance and capacity characteristics. Therefore, the infrastructure cost is allocated by the number of disks. In theory, weighting disks by their capacity and performance figures would allow for technically precise allocation, but again, this would add unnecessary complexity.

Table 51: Storage infrastructure unit cost

Cost item	Usable capacity	Number of disks
EMC Unity		
Fast SSD disk space	36,8 TB	28
Slow SAS disk space	144,0 TB	34
EMC VNX		
Fast SSD+SAS disk space	30,8 TB	80
Slow SAS disk space	92,4 TB	37
Total capacity		
Fast SSD disk space	67,6 TB	108
Slow disk space	236,4 TB	71
Storage systems total	304,0 TB	179
Storage infrastructure total cost per disk		356 €

Disk space unit cost requires some consideration. First, there are two storage systems, whose chassis are purchased at different time and disks are added several times. In addition, the older EMC VNX array is designed for spinning disks and the new EMC Unity is built as an all-flash array. Over the years, technology evolves increasing capacity and performance, and at the same time, prices tend to go down. In EMC Unity, all virtual machines in production use run on flash, or SSD, disks, whereas in the older VNX system, virtual machines consume a combined pool of SSD and spinning disks. Taking all of this into account would make calculations unnecessary complex and therefore, the decision is made to use the cost of the newer Unity system SSD disk space as the storage cost for all virtual machines. The use of VNX prices would add the cost somewhat but the use of the few years old disk prices would not make sense, because those prices do not represent in any way the current market prices. In other words, when new disk space is added, the cost of Unity disk space represents better the then-current purchase price of similar SSD disk. In addition, no new disk space is added to the older VNX system, as it will be replaced in next few years.

Table 52 presents the storage capacity total costs using EMC Unity disk space.

Table 52: Storage capacity total cost

EMC Unity fast SSD disk space	
Depreciation	16 156 €
Life cycle, years	5
Investment cost 28 x 1.6TB SSD disks	80 780 €
Storage infrastructure cost, 28 disks	9 978 €
Total cost	26 134 €
EMC Unity slow SAS disk space	
Depreciation	7 160 €
Life cycle, years	5
Investment cost 34 x 6TB SAS disks	35 802 €
Storage infrastructure cost, 34 disks	12 116 €
Total cost	19 276 €
Storage capacity total cost	45 410 €

The total cost presents the cost of all the disk space currently available for use in Unity storage system. In order to determine the cost of disk space currently in use, the amount of disk space allocated to services is obtained from the storage system and presented in table 53. Allocated disk space is the capacity provisioned for various servers from the storage systems perspective, and it is not the same as disk space used by the server itself. The storage system is able to report the actual used disk space used by file services, but not on the block storage provisioned to servers. Therefore, allocated disk space is the best measure available.

Table 53: Storage capacity usage

Service	Allocated SSD	%	Allocated SAS	%	Allocated total	%
File	0,0 TB	0 %	36,0 TB	69 %	36,0 TB	52 %
Server virtualization	16,0 TB	96 %	13,2 TB	25 %	29,3 TB	42 %
Private cloud	0,2 TB	1 %	3,2 TB	6 %	3,4 TB	5 %
Other	0,4 TB	2 %	0,0 TB	0 %	0,4 TB	1 %
Total	16,6 TB	100 %	52,4 TB	100 %	69,0 TB	100 %

Using the total cost per disk type, the unit costs for both total usable and allocated disk space per disk type are calculated and presented in table 54. The cost for allocated disk space presents the cost for currently used capacity, whereas the cost for usable disk space would apply if all available capacity were in use. Note that unit cost of usable disk space is determined using the net space, not the raw gross space. Usable disk space depends on RAID configuration, so figures presented here are applicable only in this particular case. Monthly costs are provided as a reference.

Table 54: Storage capacity unit costs

	Capacity	€/TB/y	€/TB/mo	c/GB/mo
Fast SSD disk space				
Usable disk space, 23 x 1.6TB SSD	36,8 TB	710 €	59,18 €	5,78 c
Allocated disk space	16,6 TB	1 574 €	131,19 €	12,81 c
Slow SAS disk space				
Usable disk space, 24 x 6TB SAS	144,0 TB	134 €	11,16 €	1,09 c
Allocated disk space	52,4 TB	368 €	30,66 €	2,99 c

Lastly, the total cost of disk space used by server virtualization is computed and presented in table 55. The cost is based on actual capacity used by virtual servers. Amounts of used disk space are averages of several data points and are discussed in chapter on virtual machines. As discussed above, the cost of disk space is determined using the disk space cost of EMC Unity array. Therefore, the cost is not 100% accurate regarding present production environment, as part of the virtual servers consume disk space in EMC VNX array. However, the Unity cost represents better the current market price and the error is not significant, as approximately 75% of virtual servers and 85% of the capacity run on Unity.

Table 55: Server virtualization storage capacity total cost

Cost object	Used	Unit cost	Total
Fast SSD disk space	18,5 TB	1 574 €	29 182 €
Slow SAS disk space	16,0 TB	368 €	5 879 €
Total	34,5 TB		35 061 €

6.10 Virtualization system software

Virtualization system is a software layer between physical server hardware and the actual server operating system. VMware vSphere hypervisor is used and its costs comprise of software investment cost and yearly support fees. License cost are presented for 20 processors, representing 10 servers with two processors in each. In this thesis, VMware licences are depreciated in ten years, although it is believed they will be used much longer. Virtualization software is licensed per physical processor; therefore, unit cost is also determined per processor. Costs are presented in table 56.

Table 56: Virtualization system software total cost

Depreciation	2 805 €
Life cycle, years	10
Investment costs	28 051 €
Operating costs	10 185 €
Support	10 185 €
Server virtualization licenses total cost	12 990 €
Total cost per processor	649 €

6.11 Server virtualization backup

There are many different arrangements in use for backing up data. In this thesis, only the backup equipment and software used to backup virtual machines are discussed. Virtual machine backup consists of deduplication storage system and a backup software.

The deduplication system total cost is presented in table 57. Three backup devices are being monitored, hence 33% of total monitoring cost for the single deduplication device. Labour and overhead costs are not determined at backup system level. It is estimated, that half of the backup labour cost concern end user activities and the other half virtual machines. Furthermore, 20% is estimated to be a fair share for deduplication system and 30% for virtualization backup software.

Table 57: Deduplication backup system total cost

Depreciation	22 070 €
Life cycle, years	5
Investment costs	110 348 €
Operating costs	4 643 €
Energy	1 696 €
Data center facilities	1 064 €
Monitoring, 33% of backup	81 €
Direct labour, 20% of backup	1 652 €
General overhead, 20% of backup	151 €
Deduplication total cost	26 713 €

In order to determine deduplication unit cost, capacity after deduplication is needed. Deduplication ratio depend on actual data and therefore varies over time and use case. Deduplication system has been monitored over time and deduplication ratio seem to be around 9,5 to 10 in this case. With the ratio of 10, total storage capacity is computed and presented in table 58.

Table 58: Deduplication system total backup capacity

Dedup system usable capacity	88 TB
Actual dedup ratio, 1 to X	10
Total usable backup capacity	880 TB

Table 59 presents used storage after deduplication.

Table 59: Deduplication backup used capacity

	Used
Server virtualization	283 TB
Desktop virtualization	19 TB
File	147 TB
Total	449 TB

With the total cost and capacity figures, deduplication storage unit cost is calculated and presented in table 60. Monthly costs are provided as a reference.

Table 60: Deduplication backup capacity unit cost

	€/TB/y	€/TB/mo	c/GB/mo
Total capacity	30 €	2,53 €	0,25 c
Used capacity	60 €	4,96 €	0,48 c

With the unit cost, total cost for deduplication storage capacity used by server virtualization is computed and presented in table 61.

Table 61: Server virtualization backup capacity total cost

	Used	Unit cost	Total
Deduplication storage capacity	283 TB	60 €	16 849 €

Finally, the cost of virtualization backup software is determined and presented in table 62. As with virtualization, backup software too is licensed per server processor, 20 in total, hence the unit cost per processor.

Table 62: Backup software total cost

Depreciation	5 892 €
Life cycle, years	5
Investment costs	29 458 €
Operating costs	2 478 €
Direct labour, 30% of backup total	2 478 €
Backup software total cost	8 369 €
Total cost per processor	418 €

6.12 Virtual servers

Virtual server statistics are needed for various calculations. Statistics are gathered once in February and once in a week in four-week period in May 2017. Data is presented in tables 63 and 64.

Table 63: Virtual server statistics

	8.2.2017			2.5.2017		
	All	Pwr On	Normal	All	Pwr On	Normal
Virtual servers	379	280	277	391	302	299
Storage						
Provisioned capacity	51,3 TB	44,9 TB	34,5 TB	51,1 TB	43,9 TB	33,3 TB
Used capacity						
Fast disk space	18,5 TB			18,8 TB		
Slow disk space	16,1 TB			15,9 TB		
Total used capacity	34,5 TB			34,7 TB		
Memory						
Provisioned capacity	2,7 TB	2,1 TB	1,8 TB	3,0 TB	2,3 TB	2,1 TB

Table 64: Virtual server statistics, continued

12.5.2017			18.5.2017			24.5.2017		
All	Pwr On	Normal	All	Pwr On	Normal	All	Pwr On	Normal
371	280	277	374	280	277	375	281	278
50,2 TB	42,9 TB	32,4 TB	52,4 TB	44,9 TB	34,4 TB	52,5 TB	45,1 TB	34,5 TB
18,5 TB			18,5 TB			18,4 TB		
15,9 TB			16,0 TB			16,1 TB		
34,4 TB			34,5 TB			34,5 TB		
2,8 TB	2,1 TB	1,9 TB	2,8 TB	2,1 TB	1,9 TB	2,8 TB	2,1 TB	1,9 TB

Data on provisioned storage and memory is collected for all, powered on and normalized number of virtual machines. All includes every virtual machine in system, including running and shutdown hosts. Powered on, as the name implies, includes only powered on machines, which are in active use. Powered on virtual machine consume all infrastructure resources, whereas powered off virtual machines consume only disk space. Normalized figure represents the 99th percentile, where three most resource intense virtual machines are removed. These three machines run the Microsoft System Center Configuration Manager used in workstation management and are provisioned for unusually large amount of disk space and memory. Therefore, the normalized figures represent more accurately a typical virtual machine in production use.

The collected values are then averaged and presented in table 65, and are used in various resource usage and product cost calculations. For example, the normalized number of 282 virtual servers is used when calculation the cost of virtual machine based on used capacity.

Table 65: Virtual server statistics used in product cost calculations

	All	Pwr On	Normal
Virtual servers	378	285	282
Storage			
Provisioned capacity	51,5 TB	44,3 TB	33,8 TB
Used capacity			
Fast disk space	18,5 TB		
Slow disk space	16,0 TB		
Total used capacity	34,5 TB		
Memory			
Provisioned capacity	2,8 TB	2,1 TB	1,9 TB

In order to determine the maximum number of average virtual machine the system can support; a few additional calculations are needed. Using the averaged figures, resources depicting an average virtual machine can be calculated. Typical limiting factors are processor, storage and memory capacity. Since the number of virtual machine processors is not an issue, average figures for virtual machine storage and memory are calculated and presented in table 66.

Table 66: Virtual server provisioned resources

Provisioned resource	All	Pwr On	Normal
Storage	140 GB	160 GB	123 GB
Memory	7,7 GB	7,7 GB	7,0 GB

As can be seen, a typical virtual machine has been provisioned for 123GB storage and 7GB memory. For a reference, a typical virtual machine has two virtual processors.

Table 67 present the capacity figures for the whole server virtualization system. Note that not all capacity can be used in order to maintain high availability. The percentage of HA capacity is dependent on the server topology. In this case, there are two separate virtualization clusters, meaning that one virtualization server per cluster can be taken offline without disruption and hence a maximum of 80% can be used.

Table 67: Virtualization system total capacity

Virtualization hosts	
Total number of hosts	10
Hosts required for HA	8
HA capacity percentage	80 %
Storage	
Total capacity	57,2 TB
Available HA capacity	45,8 TB
Memory	
Total capacity	4,0 TB
Available HA capacity	3,2 TB

By using the available capacity and average resources, the maximum numbers of average virtual machines the system can support are calculated and presented in table 68.

Table 68: Maximum number of virtual servers per limiting resource

Limiting resource	All	Pwr On	Normal
Storage	336	294	381
Memory	428	424	470

These numbers should be interpreted with a careful thought. When hardware resources are unchanged, the system can naturally support much more virtual machines with below average resources, and less with above average resources. Some resources are added more easily, both technically and economically, than others. For example, currently storage is the more limiting factor but storage is relatively easy to add. There is always some amount of available capacity in storage arrays, in which case adding already purchased capacity to server virtualization’s use does not increase overall costs. On the contrary, with respect to costs happens that unit cost decreases when the total cost is allocated to increased usage. Memory, on the other hand, means practically always the purchase of a new server, as the memory slots of existing virtualization servers are typically fully equipped. Additional memory has the cost of server, but also the costs of virtualization software and backup software, as the licensing of these is tied to number of processors. Therefore, which limiting number to use, depends on the situation in hand. In general, the number of normalized virtual machines limited by memory is used, which in this case is 470.

6.13 Activity cost rates

After determining all the infrastructure costs, the resource and activity cost rates directly related to virtual servers are summarized in table 69.

Table 69: Virtual server activity cost rates

Activity or resource	Cost type	Cost behav-iour	Cost hierarchy category	Total cost	Total quantity of used cost-alloca-tion base		Cost rate	
Backup software	Direct	Semi-variable	Batch-level	8 369 €	20	processors	418 €	per CPU
Backup storage capacity	Direct	Variable	Output-unit-level	16 849 €	283	tera bytes	60 €	per TB
Data center network	Indirect	Fixed	Facility sustaining	97 382 €	285	virtual servers	342 €	per virtual server
Direct labour	Direct	Fixed	Output-unit-level	29 224 €	0,46	person-year	63 531 €	per per-son-year
General overhead	Indirect	Fixed	Facility sustaining	2 667 €	0,46	person-year	5 797 €	per per-son-year
Storage capacity, fast SSD	Direct	Variable	Output-unit-level	29 182 €	18,5	tera bytes	1 574 €	per TB
Storage capacity, slow SAS	Direct	Variable	Output-unit-level	5 879 €	16,0	tera bytes	368 €	per TB
Virtualization blade servers	Direct	Semi-variable	Batch-level	41 172 €	10	servers	4 117 €	per server
Virtualization software	Direct	Semi-variable	Batch-level	12 990 €	20	processors	649 €	per CPU

First of all, costs are either direct or indirect in relation to the cost object, a virtual sever. Overhead and data center network costs are indirect, all the rest of the resources and activities possess a direct link with virtual servers. For example, when a new server is added, total used disk space increases by the amount allocated to the new server. Depending on the type of resource in question, costs behave differently in relation to number of virtual servers. Storage capacity used increases as the number of virtual servers increases or if capacity is added to existing servers, therefore it is variable cost. Data center network and overhead costs are fixed, they incur regardless of the number of virtual servers.

Backup software, virtualization blade server and virtualization software costs are semi-variable costs, having both fixed and variable component. Until certain capacity thresholds are reached, these costs remain the same although the number of virtual servers increases. When thresholds are reached, additional capacity must be added and costs increase to a new fixed level with new threshold limits.

Costs belong to different categories depending on their relationship with virtual server. Output unit -level costs are related to single virtual server. Batch level costs are associated with number of virtual servers, typically 30 to 50, that run on single physical virtualization server. These costs increase when a new virtualization server is added. Product-sustaining costs are those costs caused by the server virtualization as a whole, such as the costs for virtualization system software. To be precise, there is a product-sustaining component in virtualization software. All virtualization system software costs are categorized as batch-level costs, as the cost of management server license represents only 2% of the total cost. Facility sustaining costs, such as overhead and data center network, are related to all services, not just virtual servers, and are caused by the decision to produce IT services. In the context of server virtualization, output unit and batch level costs increase, when the number of virtual servers increase. They can be avoided by not adding virtual servers. Product-sustaining costs do not increase with the number of virtual machines and they incur as long as there is server virtualization in use. Facilities sustaining costs have practically no dependence with number of virtual server and incur as long as IT services are being produced.

6.14 Server virtualization total cost

The cost of server virtualization for the base scenario is calculated and presented in table 70. In the base scenario, unit costs per item are determined for the average of 282 normalized virtual servers currently in active production use, with the exception that data center network activity cost is provided for all the 285 powered-on active hosts. The difference of three is the number of servers removed in the normalization process.

Table 70: Server virtualization total cost in base scenario

	Total cost		Unit cost	
	Cost	%	VM/y	VM/mo
Direct costs				
Direct labour				
0,46 person-year @ 63531€/p-y.	29 224 €	12 %	104 €	8,65 €
Virtualization servers				
10 servers @ 4117€/server	41 172 €	17 %	146 €	12,18 €
Virtualization software				
20 CPU's @ 649€/CPU	12 990 €	5 %	46 €	3,84 €
Storage capacity				
18,5TB SSD @ 1574€/TB	29 182 €	12 %	104 €	8,64 €
16TB SAS @ 368€/TB	5 879 €	2 %	21 €	1,74 €
Backup storage capacity				
283TB SAS @ 60€/TB	16 849 €	7 %	60 €	4,99 €
Backup software				
20 CPU's @ 418€/CPU	8 369 €	3 %	30 €	2,48 €
Total direct costs	143 665 €	59 %	510 €	42,51 €
Indirect costs				
Data center network				
285 hosts @ 342€/host	97 382 €	40 %	346 €	28,82 €
General overhead costs				
0,46 person-year @ 5797€/person-year	2 667 €	1 %	9 €	0,79 €
Total indirect costs	100 049 €	41 %	355 €	29,61 €
Total costs	243 714 €	100 %	865 €	72,12 €

Only the direct resources consumed by virtual servers and first-level indirect cost related to virtual servers are presented here. For example, data center facilities, electricity and other indirect costs are accounted for as direct costs of respective costs objects, such as servers, storage and network equipment. The individual resources used along with their respective cost rates are provided for clarity. The cost rates are rounded; therefore, the multiplication of the two does not exactly match the figure in cost column.

The above presented data answers the question of how much is the present unit cost. Table 71 presents the server virtualization costs based on the maximum number of 470 average virtual machines, limited by the amount of memory available, the current infrastructure can run. This answer the question of how much would the unit cost be, if all the present server memory resources are consumed by a maximum number of average virtual machines. The unit cost of maximum capacity may be of help in determining a valid range for the cost, for example in pricing decisions.

Table 71: Server virtualization total cost, maximum scenario

	Total cost		Unit cost	
	Cost	%	VM/y	VM/mo
Direct costs				
Direct labour				
0,46 person-year @ 63531€/p-y.	29 224 €	10 %	62 €	5,18 €
Virtualization servers				
10 servers @ 4117€/server	41 172 €	14 %	88 €	7,30 €
Virtualization software				
20 CPU's @ 649€/CPU	12 990 €	4 %	28 €	2,30 €
Storage capacity				
30,9TB SSD @ 1574€/TB	48 636 €	17 %	103 €	8,62 €
26,6TB SAS @ 368€/TB	9 799 €	3 %	21 €	1,74 €
Backup storage capacity				
472TB SAS @ 42€/TB	19 769 €	7 %	42 €	3,50 €
Backup software				
20 CPU's @ 418€/CPU	8 369 €	3 %	18 €	1,48 €
Total direct costs	169 959 €	59 %	361 €	30,12 €
Indirect costs				
Data center network				
470 hosts @ 249€/host	117 233 €	40 %	249 €	20,77 €
General overhead costs				
0,46 person-year @ 5797€/person-year	2 667 €	1 %	6 €	0,47 €
Total indirect costs	119 900 €	41 %	255 €	21,25 €
Total costs	289 859 €	100 %	616 €	51,37 €

What is striking in the cost structure is that after thorough operations and cost analysis, only 59% of the total cost are traced as direct costs. In general, the larger the share of direct costs, the more confident one can be regarding the reliability of the total cost. In addition, it can be surprising that the data center network activity constitutes such a large share of the total cost, even though the cost object is a virtual server. However, the fact is that network is the most critical component in data center environment. For example, a virtual server cannot even boot without the use of network, as the boot and data disk reside in network attached storage array; servers cannot communicate with each other without network and end users cannot access any IT services without the use of network connectivity. In addition, the technological advances in silicon has made the servers so fast, that computing power has not been an issue for a long time. Simultaneously, the prices of server and storage capacity has decreased. As can be seen from the cost structure, servers and storage together comprise of only 31% of the total cost of a virtual server.

Coming back to the large share of indirect cost, the data center network activity is indirect activity in relation to the cost object and responsible for 40% of total cost. While in general the large share of indirect costs may be an issue, this is not the case in this thesis. As discussed in the chapter in question, practically all of the individual cost items comprising the data center network activity cost are well documented and therefore reliable. The allocation is done using activity-based costing as precisely as is feasible in order to meet the objectives of this thesis and the result is believed to represent a fair share of the costs server virtualization should bear. If it is assumed that data center network cost allocation is in practice as accurate as are the direct costs, then there are only 1% of truly indirect overhead costs.

In addition, the share of direct costs can be increased by developing more sophisticated methods for tracing the costs of individual network devices. This is not in the scope of this thesis, as it would require developing both the processes and systems for automatically gathering and analysing large amounts of volume data. It is left to further research whether the refinement of allocation schemes is good use of resources, as it is believed that the available data and results are more than adequate to support the present needs in decision making.

For a reference, table 72 present the total cost of server virtualization for the base scenario with monitoring as a whole, backup, load balancing and VPN remote access excluded. While all these are available and used by virtual servers in production use, the cost of a basic virtual server excluding these supplementary services may be helpful when comparing the cost with prices of commercial service providers. Typically, the cloud vendor’s price of virtual server includes none of these supplementary services and may include not so easy to understand traffic or other volume based charges.

Table 72: Server virtualization total cost in base scenario, excluding supplementary services

	Total cost		Unit cost	
	Cost	%	VM/y	VM/mo
Direct costs				
Direct labour				
0,46 person-year @ 63531€/p-y.	29 224 €	15 %	104 €	8,65 €
Virtualization servers				
10 servers @ 4117€/server	39 907 €	21 %	142 €	11,81 €
Virtualization software				
20 CPU's @ 649€/CPU	12 990 €	7 %	46 €	3,84 €
Storage capacity				
18,5TB SSD @ 1574€/TB	28 997 €	15 %	103 €	8,58 €
16TB SAS @ 368€/TB	5 818 €	3 %	21 €	1,72 €
Total direct costs	116 937 €	62 %	415 €	34,60 €
Indirect costs				
Data center network				
285 hosts @ 342€/host	70 448 €	37 %	250 €	20,85 €
General overhead costs				
0,46 person-year @ 5797€/person-year	2 667 €	1 %	9 €	0,79 €
Total indirect costs	73 114 €	38 %	260 €	21,64 €
Total costs	190 051 €	100 %	675 €	56,24 €

Accordingly, table 73 present the cost of more basic virtual server with maximum capacity.

Table 73: Server virtualization total cost, maximum scenario, excluding supplementary services

	Total cost		Unit cost	
	Cost	%	VM/y	VM/mo
Direct costs				
Direct labour				
0,46 person-year @ 63531€/p-y.	29 224 €	11 %	62 €	5,18 €
Virtualization servers				
10 servers @ 4117€/server	39 907 €	15 %	85 €	7,07 €
Virtualization software				
20 CPU's @ 649€/CPU	12 990 €	5 %	28 €	2,30 €
Storage capacity				
30,9TB SSD @ 1574€/TB	48 329 €	19 %	103 €	8,56 €
26,6TB SAS @ 368€/TB	9 697 €	4 %	21 €	1,72 €
Total direct costs	140 147 €	54 %	298 €	24,83 €
Indirect costs				
Data center network				
470 hosts @ 249€/host	116 089 €	45 %	247 €	20,57 €
General overhead costs				
0,46 person-year @ 5797€/person-year	2 667 €	1 %	6 €	0,47 €
Total indirect costs	118 756 €	46 %	253 €	21,04 €
Total costs	258 902 €	100 %	551 €	45,88 €

6.15 Cost of virtual Linux and Windows server

Although not in the scope of this thesis, an approximate cost for both virtualized Windows and Linux server is provided as a reference in table 74. In short, the current average cost of virtual server up to an updated operating system is 1604€ per year. Maintenance includes labour costs for routine updates and other maintenance work for operating system and commonly used server side applications. No costs for special application, labour or resource needs are included. Maintenance cost is only a rough estimate and is not based on any actual labour usage. Note that there is no error in license costs. OS license costs are determined by dividing cost of academic server license for virtualization environment by the number of servers running with respective OS, and Red Hat Enterprise Linux do cost more than Microsoft Windows Server.

Table 74: Cost of virtual Linux and Windows server

	Windows	Linux
Virtual server	865 €	865 €
OS license	20 €	94 €
OS maintenance	600 €	600 €
Monitoring	81 €	81 €
Total	1 567 €	1 641 €

7 Discussion on product cost

After determining total cost for server virtualization, the question of how much does a virtual server cost is still somewhat unanswered - the answer is “it depends”. As can be seen from the product cost calculations, there are actually four different cost figures. There is no single figure that would represent the cost of a virtual server in all situations. Instead, what cost to use depends on which variables needs to be taken into account in a given situation. In the presented product cost calculations are two variables affecting price, namely the level of supplementary infrastructure services included and capacity. For example, if it were desired to compare the cost of present server base with cloud vendors, then the unit cost of actual capacity with basic configuration would probably best match the external offering. On the other hand, if a price needs to be quoted for large number of virtual servers for complex application, then the unit cost of maximum capacity with all infrastructure services included may be the best starting point. Regarding the difficulty of determining the proper cost, the product cost is discussed from different perspectives in the following chapters.

7.1 Principle of full costing

All the presented product costs in this thesis represent full costing, meaning that the product cost includes all manufacturing costs that were possible to identify with reasonable effort. Referring to full or absorption costing method, marketing and administration costs, other than the included System Maintenance overhead, normally presented in income statement as periodic costs are omitted here. Special attention has been paid to ensure, that costing is full in a sense, that no costs would be left unallocated even though only server virtualization is the primary cost object in this thesis. Specifically, all capacity related cost rates are computed according to actual used capacity, not the total available capacity. For example, there are always extra capacity available in storage arrays, blade server chassis and all the network equipment. Considering the cost of present production volume, the use of unit cost for total available capacity would lead to artificially low product cost. This kind of practice would be misleading, as there is currently no intention to significantly increase the production volume. However, if some of the available capacity are put to use, then the costs are recalculated where applicable, as illustrated in product cost at maximum capacity limited by the current virtualization server memory.

7.2 Relevant costs

The main motivation of this thesis is to provide accurate total cost information for internal decision making and benchmarking. The product cost presented includes all cost items that have been economically feasible to account for and this decision serves well the internal use of the cost data. Regarding decision making among alternative courses of action, it is of utmost importance to understand that the product cost presented includes depreciations. For example, in outsourcing considerations only relevant costs are to be taken into account and the decision is to be made by comparing the relevant cash flows of proposed alternatives. Depreciations are sunk costs and therefore irrelevant. If the decision-making situation is about choosing among alternative courses of future action, the product cost presented must be adjusted to include only relevant costs in the given situation.

7.3 Cost benchmarking

Regarding the internal use of cost data, the presented total costs figures should not require any further explanation, as the total cost includes all costs that can be accounted for with reasonable effort. In external comparison, the resources of average virtual machine and all the infrastructure services that are included in the cost must be taken into account. For example, the average virtual server in Metropolia has relatively large and high-performance resources and in the cost is also included supplementary infrastructure services such as monitoring, backup, advanced firewalling and load balancing, for which commercial vendors charge extra fees. In addition, cloud vendors typically charge each resource individually according to usage. For example, network traffic and storage transactions may be charged separately by usage, making price comparison difficult. It has to be noted that fair comparison with commercial vendors would require request for quotation and making sure that the offerings are comparable. Prices for capacity tend to decrease when requested volume increases. In addition, there are many well-known service providers who do not offer public price lists, as prices are determined case by case.

In spite of all the shortcomings, a preliminary benchmarking was carried out and the results are presented in table 75. The price column presents the publicly available selling prices of one virtual server for commercial vendors and the calculated product cost for Metropolia. The cost and price information presented applies in internal use cases, e.g. in IT cost chargeback and small scale, single project outsourcing decisions, where the capacity required typically involves one or a few virtual servers. For example, the average cost of basic virtual server in Metropolia is 675€/year, which compares roughly to Microsoft Azure Standard D2 virtual server with a yearly price of 1099€. Roughly similar Amazon’s offering has an estimated price of 826€ but comes with less storage. Neither the product costs calculated nor selling prices presented applies in large scale outsourcing considerations.

Benchmarks include the large international cloud providers Amazon and Microsoft, along with several Finnish providers found with Google search providing web-based pricing tool. Each vendor’s virtual machine is configured with as similar resources as possible. None are, however, identical as they all have differences in pricing models and technical details. Therefore, the comparison is by no means perfect and thus too far-reaching conclusions should not be made. Put simply, a virtual server service in Metropolia has a rich set of features and capacity is not limited, whereas commercial vendors’ price includes minimal or limited resources, less features and may not include all costs. Conclusions are left to reader, but it should be safe to say, that Metropolia’s offering seems at least competitive. The selling prices of commercial vendors will most certainly decrease as volume requested increases. However, the own production has the potential to further reduce the cost level and the unit cost will decrease with an increase in volume.

Table 75: Virtual server cost comparison

	Processor	Memory	Disk space	Price
Metropolia, max VM's, basic 1)	2 vCPU	7 GB	123 GB SSD	551 €
Metropolia, max VM's	2 vCPU	7 GB	123 GB SSD	616 €
Metropolia, actual VM's, basic 1)	2 vCPU	7 GB	123 GB SSD	675 €
Amazon EC2 Reserved m3.large 2)	2 vCPU	7,5 GB	32 GB SSD	826 €
Metropolia, actual VM's	2 vCPU	7 GB	123 GB SSD	865 €
Nebula Prepaid 1-year 3)	2 vCPU	8 GB	50 GB slow, 73 GB fast	970 €
Avaruus 4)	2 vCPU	7 GB	120 GB SSD	1 055 €
Microsoft Azure Standard D2 5)	2 vCPU	7 GB	100 GB	1 099 €
Neutech 6)	2 vCPU	7 GB	100 GB	1 428 €
Nebula Prepaid On-Demand 3)	2 vCPU	8 GB	50 GB slow, 73 GB fast	1 557 €
Woima Hosting 7)	2 vCPU	8 GB	120 GB	1 745 €
Zoner 8)	2 vCPU	7 GB	125 GB SSD	2 034 €
Planeetta Internet 9)	2 vCPU	7 GB	125 GB SSD	2 913 €

1) Excluding monitoring, backup, load balancing, VPN
2) Payment all upfront, data transfer costs not included, EUR/USD 1,1449.
https://aws.amazon.com/ec2/pricing/reserved-instances/pricing/
3) 50GB of slow disk space always included. https://my.nebula.fi/#/shopping-cart/
4) https://www.avaruus.net/palvelut/palvelimet/
5) https://azure.microsoft.com/en-us/pricing/calculator/preview/
6) https://www.neutech.fi/tilaus/
7) https://woima.fi/vps
8) https://www.zoner.fi/pilvipalvelin-hinnasto/
9) https://www.planeetta.net/palvelin/tilauslomake.html

7.4 Sensitivity analysis

As discussed in previous chapters, the total product cost contains some discretionary items. In order to gain an understanding how significant effect a possible false assumption on an uncertain item may cause, a simple sensitivity analysis is performed. Special attention is paid to the examination of too conservative estimates, possibly causing the cost of virtual machine appear too low. Table 76 presents different scenarios with respective effect on product cost.

Table 76: Product cost sensitivity analysis

Scenario	Product cost	Change €	Change %
Base	865 €	-	-
Labour: Server virtualization increased to 1 person-year	998 €	133 €	15,4 %
Labour: DC network increased to 0,5 person-year	885 €	19 €	2,2 %
Overhead: Average rent of 12,05€ for office space	869 €	3 €	0,4 %
DC facilities: Power & cooling maintenance -50%	864 €	-2 €	-0,2 %
DC facilities: Power & cooling maintenance +50%	867 €	2 €	0,2 %
DC PUE factor: Cooling losses -50%	856 €	-10 €	-1,1 %
DC PUE factor: Cooling losses +50%	875 €	10 €	1,1 %
DC network: All equipment depreciated in 4 years	966 €	101 €	11,6 %
DC network: 4-year depreciation, life cycle adjusted	855 €	-10 €	-1,2 %
DC network: End user computing included with ratio 1:10	1 115 €	250 €	28,9 %
DC network: End user computing included with ratio 1:20	1 176 €	310 €	35,8 %
DC network: 25% of costs to server virtualization, no ABC	773 €	-92 €	-10,7 %
DC network: 50% of costs to server virtualization, no ABC	1 026 €	161 €	18,6 %
DC network: 75% of costs to server virtualization, no ABC	1 280 €	414 €	47,9 %
DC network: 100% of costs to server virtualization, no ABC	1 533 €	668 €	77,2 %

The amount of labour each activity consumes is based on estimation and therefore labour costs are sensitive to errors. In System Maintenance team, there are two persons responsible for server virtualization. Since they have also many other responsibilities, in no circumstance can server virtualization bear no more than one person-year of labour. Using this oversized allocation, the product cost would increase by 15%. The increase of data center network labour to a half person-year would not cause a significant increase in product cost. However, data center network cannot be allocated much more labour as it is estimated that in System Maintenance, all network related activities in total consume only one person-year of labour.

In overhead costs, the actual location specific rents are used, which do not include allocations for common areas. This is not an issue, as there is practically no change in product cost even if the average rent in Metropolia is used as a cost for office space. In data center facilities, the actual maintenance costs for power and cooling infrastructure are unknown. There is no significant effect on the cost of virtual server even if these costs are increased significantly from the estimations used. Regarding electricity consumption, the assumptions made on cooling losses affect directly the PUE factor and therefore, the total energy consumed by IT equipment. However, while cooling losses have dramatic effect on PUE and electricity consumption, the effect on final product cost is minimal. If electricity would be a cost of System Maintenance and assumptions are roughly in line, the cost of electricity would account for only 3% of the annual total costs of around 1,6M€.

As the data shows, changes in data center network costs can have meaningful effect on product cost. In Metropolia-level, IT equipment is depreciated in four years, whereas in this thesis depreciations are handled according to individual equipment life cycle. If all data center network devices were depreciated in four years, without taking into account dates of purchases, product cost would increase by 12%. However, if adjusted with purchase dates of individual equipment, the product cost would actually decrease marginally. In this scenario, some of the equipment would be already completely depreciated but costs would still include operating expenses such as support, electricity and facilities. As discussed before, the proper weighting of end user computing in data center environment is somewhat problematic. A simple simulation can be made by dividing the number of desktop virtualization, private cloud and end user devices in data center network resource driver by 10 or 20, thus weighting servers more. This would increase virtual server cost by 29% and 36%, respectively. However, use of some random number is not feasible practice as there is no link to actual resource usage causing the costs.

Finally, data center network costs are allocated by fixed percentages to server virtualization. These numbers are provided for demonstrating the effect of activity based costing. They have no practical use, other than perhaps helping in outlining a theoretical upper limit to product cost in some worst-case scenario.

The purpose of sensitivity analysis was to examine the effects of possible false assumptions on the uncertain items. Other costs in this thesis are documented, measured or otherwise known and therefore require no similar analysis. However, further sensitivity analysis could be made e.g. on costs of different resources. For example, what would the effect on product cost be, if overhead, labour and IT equipment cost would increase or decrease 10% or 20%?

7.5 Economies of scale

In the context of IT infrastructure, a virtual server is nowadays very much a bulk product. Server virtualization has been around for a long time and has become mainstream. Many organizations maintain their own virtualization platforms, there are vast number of commercial vendors offering virtualization as a service and some organizations choose the hybrid model in order to benefit from the best of both worlds. As with many other commodity products, economies of scale and other microeconomic principles apply also in server virtualization business.

A manufacturer can benefit from economies of scale, if unit cost decreases when produced quantity increases. Economies of scale may relate to the fact that fixed costs can be divided to large production volume or that marginal cost decreases when production volume increases. Therefore, large volume producers may have cost advantage over small volume producers. Unit cost can also decrease if producing one extra unit gets cheaper when produced in larger batches. Materials, for example, may cost less, when purchase in large quantities. (Hyytinen & Maliranta, 2015, 43)

To demonstrate the economies of scale in Metropolia's IT service production, the following simplified example is provided. In addition to the two base scenarios, the actual and maximum number of virtual server, four additional scenarios are introduced. In the first scenario, one virtualization server is added, and then five more is added in the second, ten more in third and another ten in the fourth scenario, where there are 36 virtualization servers in total. Next, using the memory resources of the present average virtual server, the maximum number of virtual servers in each of the scenarios is determined. Scenarios with volumes are presented in table 77.

Table 77: Economies of scale, scenarios

Scenario	Volume
No production	0
Base, 10 servers, actual VM	282
Base, 10 servers, max VM	470
11 servers, max VM	529
16 servers, max VM	823
26 servers, max VM	1411
36 servers, max VM	1999

Cost data from base scenario is modified in order to estimate costs in each scenario and is presented in table 78. The cost data in this example is not completely accurate but realistic enough to illustrate the concept. Data is not discussed in detail, but the principle is that variable costs increase in relation to number of virtual servers and all or most of the fixed costs in base scenario are handled separately. Part of the variable cost in subsequent scenarios are extrapolated from the base scenario and therefore does not match exactly the actual production environment. Data center network costs are recalculated for each scenario in order to obtain the actual cost for each number of virtual servers. If a more accurate representation is needed, then the fixed and variable component of each expense item and maximum capacity of each resource needs to be examined more closely.

Table 78: Economies of scale, cost data

	Fixed	Variable 282VM	Variable 470VM	Variable 529VM	Variable 823VM	Variable 1411VM	Variable 1999VM
Backup software		8 369 €	8 369 €	8 796 €	10 693 €	14 429 €	18 164 €
Backup storage capacity	11 120 €	5 729 €	7 124 €	8 018 €	12 474 €	21 386 €	30 298 €
Data center network	97 382 €	0 €	19 851 €	24 510 €	41 309 €	59 943 €	70 920 €
Direct labour	29 224 €						
General overhead	2 667 €						
Storage capacity, fast SSD	11 107 €	18 075 €	30 125 €	33 906 €	52 750 €	90 438 €	128 126 €
Storage capacity, slow SAS	2 455 €	3 424 €	3 252 €	3 969 €	7 539 €	14 679 €	21 820 €
Virtualization blade servers	13 348 €	27 824 €	27 824 €	31 302 €	47 950 €	79 086 €	108 841 €
Virtualization software	302 €	12 688 €	12 688 €	13 987 €	20 481 €	33 471 €	46 461 €
Total	167 605 €	76 109 €	109 232 €	124 488 €	193 197 €	313 431 €	424 630 €
Total fixed + variable		243 714 €	276 837 €	292 093 €	360 801 €	481 036 €	592 234 €

Using the cost data, marginal and average cost for each scenario is calculated and presented in table 79.

Table 79: Economies of scale, marginal and average costs

Scenario	VM's	Fixed cost	Variable cost	Total cost	Marginal cost	Average cost
No production	0	167 605 €	0 €	167 605 €		
Base, 10 servers, actual VM's	282	167 605 €	76 109 €	243 714 €	270 €	864 €
Base, 10 servers, max VM's	470	167 605 €	109 232 €	276 837 €	176 €	589 €
11 servers, max VM's	529	167 605 €	124 488 €	292 093 €	259 €	552 €
16 servers, max VM's	823	167 605 €	193 197 €	360 801 €	234 €	438 €
26 servers, max VM's	1411	167 605 €	313 431 €	481 036 €	204 €	341 €
36 servers, max VM's	1999	167 605 €	424 630 €	592 234 €	189 €	296 €

Marginal cost is calculated by dividing the change in total cost with the change in volume. For example, in the first base scenario marginal cost of 270€ is (243714 - 167605) / (282 - 0). Note that in base scenario with maximum VM, the marginal cost is calculated in relation to no production. Average cost is calculated by dividing total cost with volume.

Although not the exact definition, marginal cost refers to the increase in total cost when one additional unit is produced. It is important to note that marginal cost is not the same as unit cost. Marginal cost measures the increase in cost when small number of extra units are produced, whereas unit cost refers to average cost of given production volume. When production volume is increased, after a certain point, further volume increase becomes more difficult and marginal cost begins to increase. For example, if limits on production capability are reached, investments on additional capacity are needed, causing marginal cost to increase. (Hyytinen & Maliranta, 2015, 17)

Figure 12 illustrates the marginal and average costs.

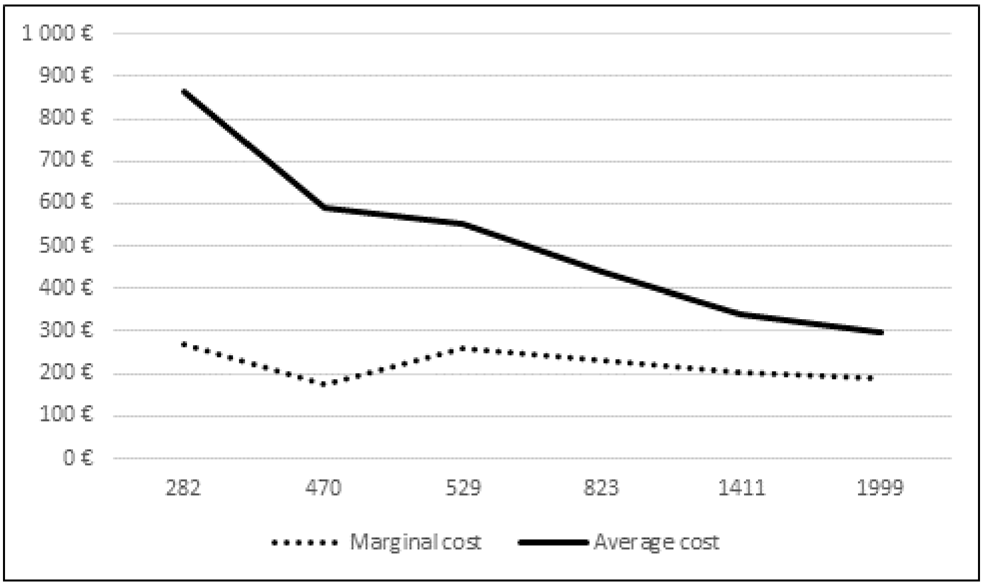

Figure 12: Economies of scale, marginal and average cost

Average cost decreases as volume increases, because fixed costs are allocated to greater number of units. Marginal cost decreases at first, as increase in volume from 282 to 470 virtual machines causes only modest increase in total cost. Depending on the point of view, marginal cost may be considered zero at this particular point. The capacity increase does not realize any additional cost, but already committed cost basis is divided to greater number of virtual servers.

In the server virtualization case, more virtual machines can be produced by adding virtualization servers, storage and backup capacity and related licenses as needed. Although these additions increase costs, all the fixed infrastructure costs such as storage and server chassis and data center network remain the same. When capacity is increased from 470 to 529 virtual servers by adding one virtualization server, marginal cost increases. This happens because volume increases less in relation to the previous point. From this point on, marginal cost decreases gradually as capacity is added.

Not shown in the figure, but eventually marginal cost will begin to increase, followed by increasing average cost. In this case, marginal cost can increase for two reasons. First of all, the price of capacity related purchases such as servers, storage space and licenses may increase, meaning that the new purchase costs more than the previous one. Secondly, at some point the number of virtual machines cannot be increased just by adding capacity, but expensive infrastructure upgrades are needed. For example, a storage system can accommodate certain number of disks and when the maximum supported number of disks is reached, a new chassis or complete storage system is needed. In both cases, marginal cost will increase as the cost of resources increases.

Marginal cost is an important concept regarding decision making in e.g. production volume and pricing. With given data, it is interesting to note that right from the outset, marginal cost is well below 300€, while average cost begins its gradual decline from 864€. The conclusion is clear: Assuming that cost data would represent close enough the actual production environment and that the cost of all produced units could be recovered, it would be economically attractive to increase the production volume. If virtual servers could be sold at average cost and required profit margin, each extra unit sold would decrease average cost of all units and there would be a comfortable margin of safety, if marginal cost were considered an absolute minimum price.

As stated, the data used does not represent exactly the actual infrastructure costs in each scenario. Exact figures would require additional cost analysis outside the scope of this thesis, but simulations have shown the probable outcome. If the amount of fixed costs increases because of proper fixed and variable costs allocation, the level of marginal cost will decrease. With 1999 virtual servers, the marginal cost may decrease at least to approximately 150€ per unit. Note that these adjustments do not affect total costs; therefore, neither behaviour nor amount of average cost changes.

In general, production is profitable when marginal cost is less than price and production should be increased up to a point where marginal cost equals price, which is when profits are maximized. If marginal cost is less than price, it is profitable to increase volume, as each extra unit will increase profits by the amount of price less marginal cost. Accordingly, if marginal cost exceeds price, volume should be decreased. Regarding pricing, at least the amount of marginal cost can be considered a minimum price for the product. In addition, prices less than marginal cost may be considered predatory pricing. (Hyytinen & Maliranta, 2015, 19-20)

Other related economic concepts are learning curve and complements in production. Learning or experience curve refers to increase in production efficiency and decrease in costs, which arises from the experience gained in production during a long timeframe. Learning curve illustrates how unit costs change in relation to cumulative production volume over time. In a graph with unit cost in vertical axis and cumulative quantity in horizontal axis, learning curve falls to the right. Steep learning curve may be significant competitive advantage, if accumulated learning and experience yield to substantial cost advantage. Products complement each other, when same raw material, production technology or other common inputs are used in production. Characteristic for complements is that they are more cost-effective to produce together than individually. In that case economies of scope are present. (Hyytinen & Maliranta, 2015, 44)

7.6 On cost-effectiveness

Regarding theories on economies of scale and related concepts, it is somewhat surprising how cost-effective the own service production may be and to what extent the unit cost can be decreased by increasing volume. Contrary to layman's assumption, that small volume producer cannot compete with large volume, perhaps international cloud vendors, the cost analysis seems to suggest that quite the opposite may be the case. Most likely, there are many possible explanations for the discrepancy. A Google search is not enough for price comparison, but in practice a tender need to be put out to find out the actual cost of similar capacity with comparable features. If there is still difference in price in favour of own production, then the explanation may be sought from pricing policies and cost structure.

One explanation for the possible cost advantage may be derived from the fact that Metropolia controls the whole value chain of the virtual server. All customary IT services including virtual servers are produced using own facilities, equipment and personnel. Excluding mandatory support services for IT equipment, software licenses and dark fibers, no IT infrastructure related services are outsourced. Buying no services means paying no profit margins. The cost of capital in Metropolia's case is low and omitted in decision making on IT investments. When compared to commercial service provider, who has to cover both the cost of IT's resources, which may be initially higher due to complex environment, and the cost of capital, which must be higher in order to cover the required return for the investor, it may very well be that Metropolia's own IT service production does enjoy some cost advantages. For example, many commercial software vendors, including Microsoft and VMware, grant substantial discounts to academic institutions. This enables, for example, the use of commercial virtualization software at a very reasonable price, instead of free of charge but more labour intensive open source software. The labour and real estate costs seem to be modest in Metropolia, along with the modest use of these resources. In addition, large-scale operations demand high-end infrastructure and/or highly skilled technical experts, especially if infrastructure is built on DIY hardware and open source software, thus increasing cost. Therefore, Metropolia may be big enough to benefit from some economies of scale in IT infrastructure, but small enough to avoid the costs and complexity of e.g. full infrastructure automation required by large-scale providers. Finally, there are also no 24/7 or strict statutory compliance requirements in the field of higher education, yet again decreasing costs.

Complements in production, as discussed earlier, may be another source of competitive advantage. Were the virtual server only product, the unit cost would naturally be higher. However, there are many other services produced by System Maintenance team sharing the same underlying infrastructure and personnel. On example is network infrastructure and internet connectivity, which is consumed by both ca. 15 000 end users and centralized data center services. There are no highly specialized experts, but every team member has diverse responsibilities. For example, the persons responsible for server virtualization are engaged e.g. in server administration and various project consulting. Versatility and agility as a modus operandi enables to offer varied service portfolio with relatively small amount of personnel and helps controlling costs.

As a conclusion, the cost-effectiveness of own IT service cannot be determined without a valid cost comparison. This thesis, however, does provide data and methods for assessing present product cost, which is a mandatory step in making intelligent make-or-buy decisions.

8 Conclusions

In this final chapter, findings of this research are discussed on the basis of presented business problem, after which the validity and reliability of this research is considered. Finally, the author will present recommendations for future actions to be considered.

8.1 Objective and outcome

The objective of this thesis was to determine the cost of server virtualization service in Metropolia University of Applied Sciences. The aim in this research was to present a valid and reliable total cost for the server virtualization service. In addition, IT infrastructure cost structure and possibilities of expanding the service production were to be investigated. This research sought answers to the following research questions:

1. How to determine a valid and reliable total cost for the server virtualization service?
2. How the IT service cost accounting can be further improved?
3. What can be concluded on the economic feasibility of selling the service provided or providing the service through shared service center?

Based on current state analysis, it was evident that much more detailed data on IT costs and volumes, and proper accounting techniques, were needed in order to determine cost of any IT service provided. Currently available data was adequate in organization level benchmarking and indicated total costs of various IT Services' functions. However, nothing specific could be concluded on costs of individual IT services.

Firstly, a conceptual framework for the research were to be developed. The concept of value chain is used as a basis for activity analysis. The framework presented discusses necessary accounting terminology and methods to ensure, that all cost will be properly accounted for. Cost are assigned as direct cost whenever possible. Indirect costs, especially the data center network costs require special attention. Activity-based costing is needed to properly allocate the indirect data center network costs to cost objects based on resource usage. The accounting model must adapt to production environment; therefore, the cost accounting is performed using a hybrid costing method, where principles of direct costing, job costing, process costing and activity-based costing are applied.

The product cost calculation is the core of this thesis and answers the main research question. The cost of server virtualization comprises many different direct and indirect IT infrastructure resources. Each of the activities and resources used in the production of server virtualization service is discussed in detail and relevant data on costs and volumes is presented. The thorough cost analysis is mandatory to ensure validity and reliability, but is beneficial also in making the cost structure visible and thus facilitates the cost analysis of other IT services provided. The main research question cannot be answered with a single figure applicable in all scenarios. Instead, the cost of virtual server is presented in multiple scenarios. Care must be taken to use proper cost information in given scenario.

Referring to second research question, the need to further develop the cost accounting model must be carefully considered. In theory, the costing system can be refined with additional data but the improvement comes with a cost. Major improvements in the accuracy of product cost will introduce more complex accounting methods and requires collecting and analysing additional volume data from numerous sources, which have to be automated. Labour costs are based on estimations, so more detailed time-tracking system would lead to accurate labour costs assignment.

As stated, there is no single answer to the main research question. In addition to cost presentation in different scenarios, a discussion is provided to further analyse various factors affecting the total cost and to provide answers to the third research question. The cost of virtual server with current volume seems to be reasonable. As the analysis shows, the cost will decrease significantly if volume can be increased from present levels of hundreds VM’s to thousands of VM’s. Of utmost importance in benchmarking and decision making is to ensure, that the cost presented is relevant in the given situation. For example, when comparing the own service level and cost to other organizations or commercial vendors, care must be taken to ensure comparability. In choosing among alternative courses of action, e.g. in make-or-buy situations, the decision is to be made based on relevant costs.

Finally, the following conclusions can be made:

- The conceptual framework presented can be used to determine a valid and reliable cost for server virtualization. In addition, the framework and data presented forms the basis for analysing cost of other IT services as well.

- The absolute cost of virtual server seems competitive based on preliminary cost comparison. However, no final conclusions on the topic can be made until more detailed market study including volume discounts is carried out.
- Further refining the costing system is possible with additional data but the economic feasibility of doing so must be considered. The cost and volume data presented should be sufficient in most of the common use cases.
- Regarding a shared service center or other approach to joint IT service production in higher education sector, there may very well exist a valid business case. The cost of virtual server will decrease dramatically, if volume can be increased to thousands of VM's. The economies of scale benefits large volume producers but in this case, the competitive advantage is to be pursued by focusing to the Finnish higher education sector and adapting the production environment and cost structure according to sector specific needs.

8.2 Validity and reliability

The research method in this thesis is case study and therefore, the findings of this thesis cannot be generalized. The very reason in choosing the case study as a method was to explore the given case as thoroughly as is economically feasible. That said, the conceptual framework and product cost calculation is discussed in detail, and it should be straightforward to apply the methods in similar case.

Critical factor in evaluating the validity of the product cost is the use of proper accounting methods. The indirect data center network costs represent some 40% of the total cost and thus, activity-based costing is used to ensure proper indirect cost allocation based on resource usage. Validity of the activity-based costing method, on the other hand, is most affected by the use of proper cost drivers. The cause-and-effect relationship between resource costs and services causing the costs is followed as far as is permitted by the available data.

To address reliability, the conceptual framework, collected data and product cost calculation are explained in detail. Using the presented framework and data, another researcher should be able to repeat the product cost calculation and reach the same results.

Regarding validity and reliability, it is important to note that some subjective choices have been made in the product cost calculation. In some cases, estimations are used due to lack of actual data of the given expense item. All of the uncertain expanse items are discussed in the product cost calculation. Some of the uncertain items, e.g. the effect of cooling losses, are further discussed in sensitivity analysis. Due to these decisions made by the accountant during the product cost calculation, other researcher using the same data may decide to handle some expense items differently, therefore reaching somewhat different product cost. This is not to be considered as lack of validity and reliability, but a reflection of the real-life situations, where the accountant must be able to make justified decisions.

8.3 Recommendations

Based on the findings in this research, the following recommendations are made.

The provided cost information should be adopted in everyday decision making to ensure efficient use of IT's resources.

- The actual production cost of virtual servers should be the basis when pricing virtual server in internal and external uses. At a minimum, price must cover marginal costs and required margin.
- Pricing should be further developed, if IT cost chargeback or large scale sales of infrastructure capacity is considered. This will require a closer analysis of infrastructure cost behaviour (fixed and variable costs, relevant ranges of resources).
- Benchmarking is encouraged. Care should be taken to make necessary adjustments to service contents and product cost to ensure comparability.
- In both small and large scale outsourcing decisions, the cost and efficient use of Metropolia's resources should always be considered. When considering large scale outsourcing or otherwise significant decisions on IT services, the conceptual framework and data should be reviewed to ensure that decision are made based on relevant costs.
- Cost awareness among IT's users should be increased. Although degree programmes and support services units are provided for "free", the cost of IT's resources should be made visible.
- The pros and cons of IT cost chargeback should be considered. On the one hand, centralized IT's resources should be utilized whenever possible because of scale

advantages but on the other hand, some way of charging the end users cost center may prove beneficial in guiding towards efficient use of scarce resources.

The conceptual framework should be developed according to future needs. For example, labour costs are estimates and to improve the product cost accuracy, the time-tracking system needs to be developed. It is to be noted, that such improvements come with a cost and therefore, the sufficiency of readily available data should be considered first.

At least the cost of most large volume IT services should be accounted for, where the conceptual framework and data presented should be of help. Making costs and activities visible increases understanding of

- what causes costs,
- what actions are needed to reduce costs,
- which activities are wasting resources, and
- which activities should be invested in to increase productivity and service quality.

Finally, the benefits of activity-based management (ABM) in reducing costs should be considered. The activity-based costing (ABC) used in the assignment of data center network costs focuses on analysing the activities causing the costs and allocating the indirect costs to cost objects based on resource usage. ABC has the view of cost assignment, while ABM focuses on processes. In ABM, the activity analysis is used to improve customer satisfaction and profitability through cost reduction and process improvements. After analysing activities, they can be classified as value added and non-value added activities. Value added activity is one which increases the usefulness of the product or service perceived by the customer. Non-value added activity, respectively, is an activity where cost can be reduced without reducing the products or services usefulness to the customer. In addition to activity-analysis, the ABM approach involves continuous improvement, benchmarking of value-added activities, business process re-engineering and quality cost management. (Drury, 2012, 549-558)

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