Fraunhofer Institut
Umwelt-, Sicherheits-,
Energietechnik UMSICHT

"PC vs. Thin Client"

Economic Evaluation

Version 1.2008

This study is based upon the document "PC vs. Thin Client – Wirtschaftlichkeitsbetrachtung". The translation has been sponsored by IGEL Technology GmbH (www.igel.com).

Version history

Datum	Anmerkung	Autor
06-22-2004	Initial version comprising the calculation models "Unmanaged PC" and "Thin Client / Server Based Computing"	Christoph Köchling, Christian Knermann
12-15-2006	Introduction of a third calculation model "Managed PC", recalculation based on new purchase prices for hard- and software	Christian Knermann
08-16-2007	Recalculation of all models based on new purchase prices for hard- and software	Christian Knermann
02-20-2008	Omission of the calculation model "Unmanaged PC", update of the remaining models based on list prices for hard- and software which apply to small to medium sized companies, reducation of expenditure related to the acquisition of PC	Christian Knermann

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1 Introduction

Rising demands on IT departments coupled with decreasing budgets are pressuring IT representatives and necessitate cost reductions as well as more efficient use of existing resources. On this basis, the term Total Cost of Ownership (TCO) is discussed. TCO should give the IT representatives a single measured value to denote the cost of acquiring and operating an IT system in their area of responsibility.

TCO is also the variable used by manufacturers as "the" argument to promote their products and services in the field. Server Based Computing is also the focus of the cost discussion and is seen by its promoters as a very effective means for sustainably reducing the cost of IT departments.

1.1 Cost reductions – the TCO discussion

The persistent cost pressure associated with growing demands and shrinking budgets more and more forces the IT representatives to sustainably reduce their operating and acquisition costs. In view of this, the Total Cost of Ownership (TCO), which is the combined cost of acquisition and operation of an IT system, is intensely and partially controversially discussed between users, manufacturers, and consultants. The reduction of TCO is employed as "the" argument by the manufacturers for the marketing of their products and services. In spite of that, or exactly because of that, the question arises what use the knowledge of TCO has for the individual IT representative and which conclusions he can draw from it for his budget planning.

Basically, the determination of TCO attempts to measure all costs related to a PC and to express it as a single value. In order to accomplish that, well known consultancies such as Gartner Group or Forrester Research have developed quantitative models or processes over the years that should give suitable support to IT representatives.

In addition to direct costs for the acquisition, startup, support and software, indirect costs for centralized services such as email, file and print services, or personnel costs of operative and strategic IT departments have to be considered; for instance, costs for peripherals are proportionately distributed to the individual workstations.

TCO also attempts to measure productivity losses of the users. Such productivity losses are caused by hardware failures or the installation of

unauthorized software for example. In recent evaluations for instance, the Gartner Group is assuming that the TCO does not decrease over longer user periods of five years but instead increases slightly [CW 2003]. This is explained by a shift of direct costs to indirect costs. Direct cost are expenses that can clearly be assigned to IT and the PC workstation such as costs for acquisition, support, maintenance contracts, etc. Additional indirect costs are generated by productivity losses caused by breakdowns and maintenance measures, or through support and self-help activities by the user.

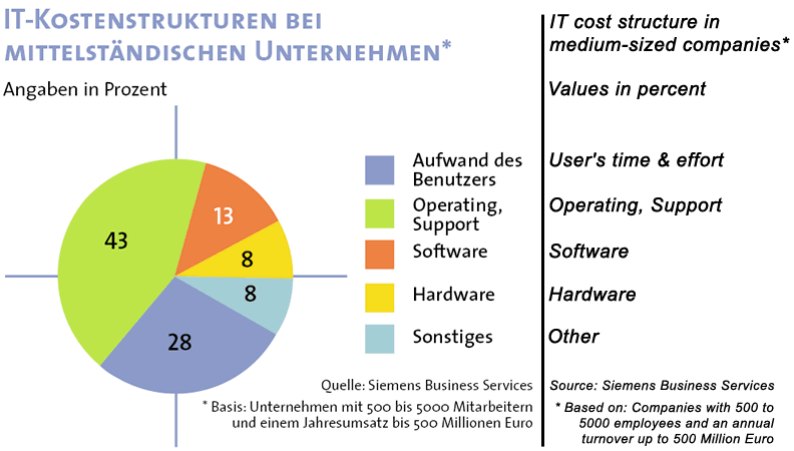
Additionally, expenses caused by the permanent need to upgrade increase the TCO. Many PCs are not able to use current software such as the present version of Office. However, these PCs are not yet depreciated and an early replacement is not planned or even possible. Instead the RAM has to be upgraded, the hard drive has to be replaced, or the graphics card has to be switched. Thus, unplanned and potentially substantial costs are accrued, especially in the support area.

The models developed by the consulting companies for the calculation of TCO vary greatly and have been modified to reflect new technical developments and new findings in recent years. This has greatly affected the comparability of individual studies.

However, it has to be cautioned not to attempt to determine the economic viability of technologies and individual IT decisions on the sole basis of TCO. TCO judges costs but not benefit. The TCO only delivers monetary statements. Quantitative or even qualitative statements beyond that are not included.

1.1.1 Acquisition costs only a portion of the total costs

Despite all legitimate criticism about the TCO, the same, indisputably important core conclusions can be found in all mathematical models. The most important message is that costs for IT systems have to be viewed holistically and over the entire utilization period in order to reach defensible and sensible business conclusions. The second important message is that the acquisition costs only represent a relatively small portion of the actual operating costs. One study showed it constituted only 21% (8% hardware and 13% software). The same study determined that instead 43% of the costs are caused by operating and support and an additional 28% by the users themselves.



1.1.2 Reduction of the TCO via Server Based Computing

Many manufacturers of Thin Clients and Server Based Computing products try to justify the benefit of their products on the basis of decreased TCO.

Based on an analysis from Zona Research in 2003 for example, the application of Server Based Computing and Thin Client technology enables a reduction of the TCO by 57%, while Siemens Business Service assumes 22% in the same case. In order to determine which savings can actually be achieved and which costs can be reduced particularly, each case might have to be investigated specifically. It is dependent on the size of the business, the personnel structure of the IT department, the homogeneity of the utilized software landscape, the main type of activity, and, of course, the applied mathematical model.

1.2 Goal

The goal of this document is to shed light on economic questions on Server Based Computing and familiarize the reader with the topic. The individual chapters are structured such that they can be examined independently of one another depending on how in-depth the reader wants to study the subject matter.

Therefore, technical details are deliberately left out of the following chapter, entitled Management Summary. The chapters about the cost models for Thin Clients and PC explain the specific costs for the operation of a work station PC and Server Based Computing in detail and comment about the topical and technical basis of specific costs.

2 Management Summary

2.1 Overview

2.1.1 Server Based Computing

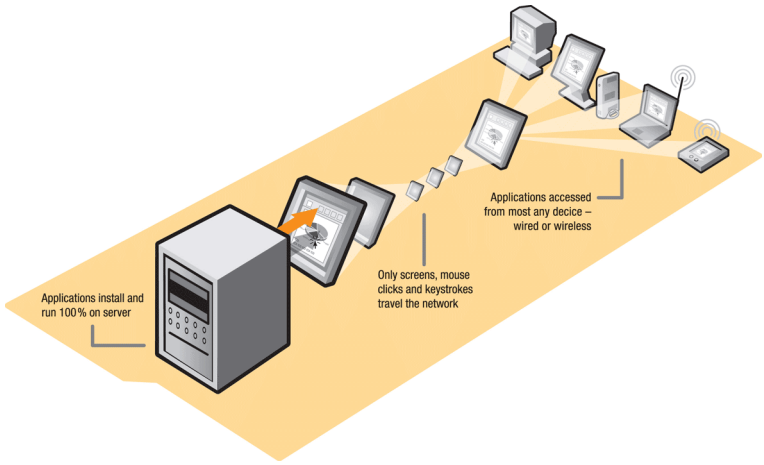
Server Based Computing (SBC), utilizes a proven procedure for information processing that has been practiced in the large-capacity computer sector for decades.

Starting in the sixties up to the beginning of the eighties, so-called terminals could be found on the desks of many employees. A terminal is a visual display unit with a connected keyboard that sends all keystrokes of the user to a centralized large-capacity computer via a network connection. On the large-capacity computer, usually a mainframe in a computing center, all the user entries are processed and the resulting output is returned back to the terminal. The terminal, therefore, does not perform significant computing or processing.

The advantages of such an approach are clear. Comparatively inexpensive units can be used at the workstation which contain significantly fewer components that can fail such as local memory compared to workstation PCs. Local software installation also becomes unnecessary which makes the terminals much less maintenance intensive and, thus, much less expensive to operate compared to PCs.

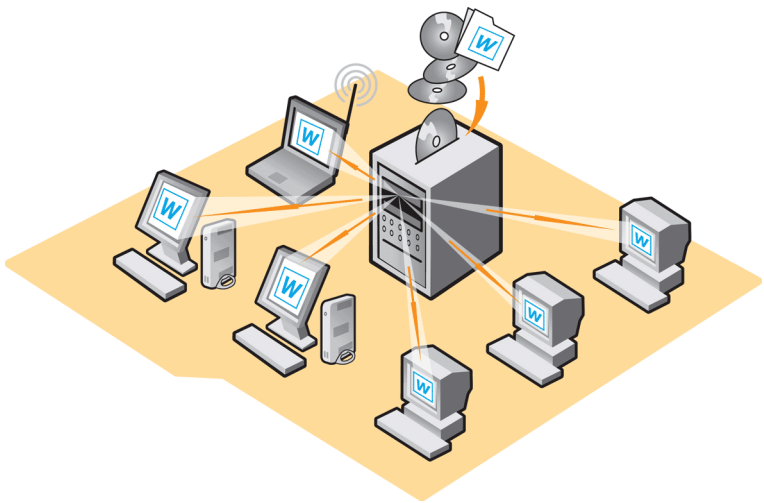
When terminals were introduced, PCs were not well known and graphic interfaces with mouse operation or other input devices other than the keyboard were not yet invented. However, after an era of local processing, an era of networks, and the utilization of software in client /server environments and the age of the internet, some of the advantages of the former terminals are more sought-after than ever when reductions in cost and effort are essential.

SBC transposes the processing principle of the terminals to the age of user interfaces. In SBC, all programs used by the user, all windows he opens or closes are performed on a powerful, centralized server system. Only the result, the computed content, is displayed on a monitor similar to the old terminals. The local keyboard entries and mouse movements including all scroll, mouse, and extra keys are sent to the central server and processed there.



Source: Citrix Systems (http://www.citrix.de)

The main difference between the terminals and the SBC is that the centralized computer is not a mainframe anymore, but instead it is a powerful server on the basis of the x86 or x64 architecture operating on Microsoft® Windows®. The utilization of the computing capacity is available via special software or a dedicated terminal, a so called Thin Client.



Source: Citrix Systems (http://www.citrix.de)

Thus, with SBC the user works with Windows® and the same software applications just as he would with a local PC. The investments in software and the training of the employees are usually unchanged when using SBC. Even more so: In many application cases the user does not even notice whether he uses a program on his local PC or remotely with a terminal server. Additional training costs or expenses for other programs usually do not occur.

The primary task of the client is the display of monitor information, which it receives with the help of a special network protocol, and the sending back of the key entries and mouse movements of the user to the so-called terminal server.

However, Thin Clients go a step further than the classic terminals. In principal, using local drives and printers as well as the replay of sounds is possible as long as the Thin Client is able to, through a local printer port for example. Thin Clients are available in different specifications. Starting with systems that simply have the ability to convert monitor entries up to systems with built-in web browser, multimedia support, or support for biometric authentification systems.

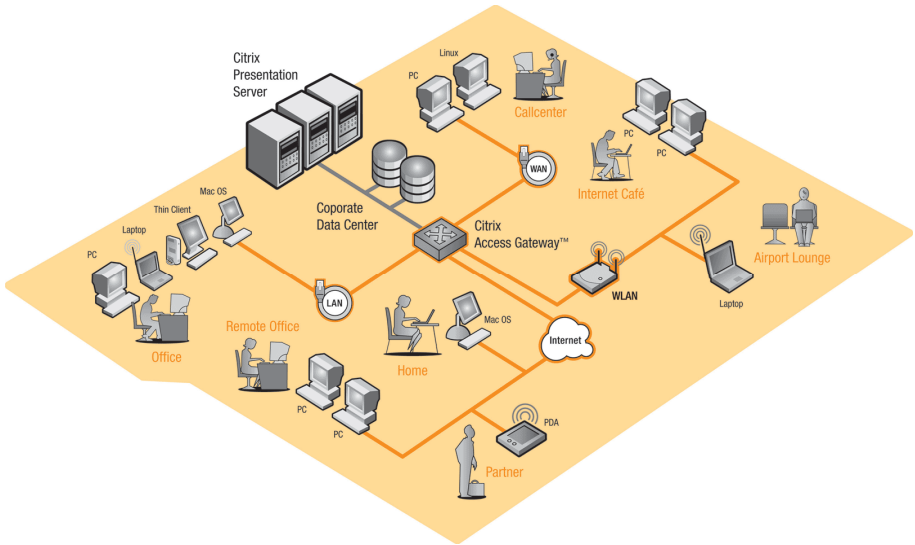
SBC is not dependent on the use of Thin Clients. As an alternative to Thin Clients, services on a terminal server can also be used from a PC, a workstation with UNIX®/LINUX® or another user device such as a PDA by using suitable add-on software.

Analogous to Thin Clients, workstation PCs are also referred to as Fat Clients based on their higher local computing capacity.

2.1.2 Prerequisites

In order to offer and use SBC, software is required in addition to a powerful server based on x86 or x64 architecture and terminals, Thin Clients or workstation PCs. The two most important software packages in this context are Microsoft® Windows® and Citrix Presentation Server™. Since the version Microsoft® Windows Server™ 2000, Windows® can be operated in a special mode which offers the terminal services and allows the simultaneous use of applications by many users. Put more simply, the activation of the Windows® terminal services makes it multi-user capable. In earlier versions, a separate product (Windows NT® 4.0 Terminal Server Edition) was necessary to accomplish that. In the most recent Version, called Microsoft® Windows Server™ 2003 R2, the function spectrum is broadened further and represents an industry-widely accepted platform for SBC.

However, Microsoft® Windows Server™ 200x only offers basic functionalities for the operation of a terminal server. If more functions are needed such as transparently providing terminal services from multiple, load-sharing servers, or using network connections with lower bandwidth (e.g. ISDN), it is advisable to additionally use the software product Citrix Presentation Server™. The Citrix Presentation Server™ employs the user protocol ICA® which is a protocol that is optimized for the application of WAN connections.



Source: Citrix Systems (http://www.citrix.de)

Naturally, an additional network infrastructure with LAN wiring, routers, and switches is required. It is worth mentioning that network connections with low bandwidth such as modems or ISDN are quite sufficient with the help of the ICA® protocol.

Not every software application is equally suitable for the utilization on a terminal server. Very computation-intensive application such as simulations and complex mathematical calculations that require long calculation times are equally unsuitable as graphic-intensive applications, picture editing systems, or CAD. Additionally, it has to be made sure that the software applications are generally multi-user capable and, accordingly, terminal server capable. Here, the adherence to a few but very crucial programming guidelines is necessary. Generally, it can be observed that the majority of available software applications are terminal compatible. In many cases, minor modifications are sufficient to make software terminal compatible. This is not possible for a few applications, however. If the software manufacturer does not explicitly guarantee the terminal capability, an evaluation and test installation should always be performed to ensure that the software can be utilized with the terminal server. In addition, the license terms of the software have to permit the installation onto a terminal server.

2.1.3 Applications

Server Based Computing is not a new concept and has established itself as a proven and widely utilized technology. This applies to medium sized businesses with maybe 50 employees as well as large companies with several thousand

users. There are many application scenarios that take advantage of the particular advantages of Server Based Computing. A selection will be briefly described below.

Cost reduction

Many businesses have positions that work with a relatively limited amount of software such as Microsoft® Office, a web browser, and a frontend for an ERP-system. The employees in these positions perform comparable tasks. If these employees are equipped with workstation PCs to fulfill their tasks, typical support duties arise that don't have anything to do with the content of the job but rather with the workstation PC as a technical component. For example, support for the failure of hardware components, local installations of user applications, updates, service packs and patches, the fixing of problems caused by the user or the installation of unauthorized software, or the necessity for local virus protection. Businesses attempt to control these costs using guidelines, administrative limitations, security concepts, etc.

The use of Thin Clients is an alternative to the workstation PC. Thin Clients not only offer cost advantages related to acquisition but also especially to the operation. These cost advantages arise mainly through the significantly reduced support requirements. If, as described in the example, only a small, defined number of software packages is needed, this is a good starting point to replace workplace PCs with Thin Clients and to operate suitable terminal servers. In this manner, the users utilize all of the necessary software through the terminal server.

Application provision

Businesses are often faced with the challenge of making critical software or new versions available for a large number of employees at different locations at the same time. For example, this could be a new release of an ERP system. On one hand, it is not possible to phase the program in and use a mixed operation because the risk of data inconsistency is present based on the dependence of the Client-GUI and the backend of the application system. On the other hand, it is virtually impossible logistically to complete the conversion for several thousand users simultaneously or over the course of a weekend. Although automatic software distribution systems make it possible to perform a remote and unsupervised installation, the requirements for that are enormous. Aside from the maintenance and the extensive testing of the software distribution systems, the Clients on which the software will be distributed have to be more or less identical. This means that the operating systems have to be the same with the same service packs and updates installed, the application paths have to be standardized, there has to be sufficient space on the drives for the

installation and the subsequent operation, etc. All these requirements have to be met prior to beginning the software distribution.

The execution of the installation necessitates the turning on of the units via the network for unsupervised installation or the installation is started automatically on the next work day when the unit is switched on by the user. The scenario of the installation initiated by the user has two problems: first, the following installation results in lost work time for the employee who can watch the completion bar during the installation, and, second, the potentially hundred or thousand times simultaneous completion of the installation can lead to a significant overload of the network and the entire server infrastructure that is used for the installation.

A simultaneous conversion using manual installation is also usually not feasible because of the enormous personnel requirements.

Whenever a rollout of an application based on a local component and with the requirements of a Fat Client has to be completed, the installation on a terminal server can be an economical and technical alternative to the mentioned methods. This can also be performed on multiple servers which are referred to as terminal server farms.

In order to accomplish that, the software is installed on the terminal server, the users that will work with the software are added to an authorization group, and that is how the application will be released to the users. If the suitable Thin Clients or workstation PCs are available, the application can be used immediately without requiring further actions from the user at the workstation.

Standard workstation or specialty applications

Two additional examples can be drawn from the above mentioned example about application provision. In both scenarios the user has a workstation PC. However, the scenarios differ in which software is installed on the workstation PC. In the first case, the workstation PC is used in a standard workstation with applications such as Microsoft® Office, email, and a web browser. These programs are installed locally and are also processed locally. However, the user uses some specialty applications via the terminal server. Such applications could be used less often or expensive products such as a hazardous material data bank, an electronic encyclopedia, or a special solicitation software. The advantage is clear: The licensing costs for these programs can be limited, the timeliness of the information can be controlled centrally, and there are no support and provision costs for local installations, etc.

The second variant takes the opposite route. Here the workstation PC is utilized to operate specialty applications with high requirements for local processing

capacity such as a CAD-system. A standard workstation with Office is provided via the terminal server. The advantage of this method is that the user can operate his local applications with the necessary resources and, at the same time, does not have to consider the standard applications when configuring the PC or even the client operating system.

Investment protection

Often businesses face the challenge of introducing new versions of applications on a company-wide basis and realize that a portion of the affected workstation PCs do not meet the requirements of the new software with regard to the CPU, storage, or hard drive space. In this case, costs for upgrades or replacements are accrued. Alternatively, the application program can also be provided over the terminal server. An ICA® Client will simply be installed on the PC of the user and he can then use the released program on the terminal server. The hardware requirements of the ICA® Client are so low that the old PC will be able to run programs via the terminal server that have high hardware requirements.

Conversely, there are investments in existing programs that have to be secured from switching to new operating systems. Therefore, these programs should be continued to be used. An example would be an operating system change from Windows® to Linux®. Such a conversion could become impossible because there are business-critical programs that are not available as a Linux® version or self-written programs that could only be converted with a disproportionately high expense. Then it would be possible to make these Windows® programs that still have to be used available on a terminal server. The necessary ICA® Client is available for a large number of operating systems.

2.1.4 Risks

As with any technology, there are also risks associated with Server Based Computing.

Since the dependence of the users on the availability of the terminal server is very large – after all they cannot do any work with a Thin Client and no terminal server -, a high availability has to be ensured. Aside from using high-quality hardware that is suitable as a server, professional management is also necessary to accomplish that. In addition to the pure server costs, the introduction of Server Based Computing will also lead to costs for the education and possible certification of the administrators.

Furthermore, reservations and skepticism of the users towards Server Based Computing have to be overcome. The loss of the workstation PC is seen as a loss of control and individuality by many users. For some users, this can go as

far as viewing a job with a Thin Client instead of a PC as second class. Thus, it is important to inform the users, to take the fears and concerns regarding the new technology seriously, and to counter them sufficiently. There are some good reasons in special cases not to use SBC, but most of the time the concerns can be successfully eliminated with the help of technical solutions and suitable concepts. An important success factor for the introduction of Server Based Computing is the performance of the system as it is experienced by the user. If this does not match the experiences from local PCs or if the response time behavior lacks to the point that a visible delay occurs between the key entry and mouse movement and the visual feedback through the terminal server, it can lead to serious acceptance problems. This acceptance problem should be prevented though generous dimensioning of the necessary hardware.

Other negative impacts on a long-term IT strategy should not be expected with the introduction of Server Based Computing. The manufacturers Microsoft and Citrix are established in the market such that a sudden disappearance from the market and the resulting lack of support for future software generations can almost be ruled out. The market for Server Based Computing is still seen as a growth market. Microsoft as well as Citrix is undisputed market leaders of their respective product categories. Therefore, Server Based Computing is not expected to be a technological dead end even in the long run.

The introduction of SBC technology is associated with higher costs at the beginning. The investment is amortized only with long-term use. Therefore, SBC should only be introduced in a business if it fits with the long-term strategy and if the desire and opportunity for the conversion are given. Short-term savings can only be realized for large companies in specific cases of application provision.

2.2 Summary

2.2.1 Boundary conditions / Generic point system

During the creation of the presented cost models, it quickly became apparent it is not possible to make a general statement for or against Server Based Computing. Rather, many parameters have to be known prior to the economic evaluation in a concrete environment. Following, these parameters are listed and are substantiated further in the chapters on the cost models:

General data about the environment

- Number of employees/workstations total
- Number of employees/workstations that can exclusively work on Thin Clients
- Employee groups that are participating in the relevant processes
- Average salary of these employee groups
- Work time per month
- Planned utilization duration of the terminals

Processes associated with the acquisition / provision

- Process initial acquisition:
    - Participating employee groups
    - Duration of an activity incl.
        - Configuration
        - Order processing
        - Initial installation
        - Rollout to the user
    - Amount of work per employee group
    - Costs for hardware / software
- Process hardware extension / replacement:
    - Participating employee groups
    - Duration of an activity incl.
        - Configuration
        - Order processing
        - Installation at the user
    - Amount of work per employee group
    - Costs of the hardware
    - Frequency of the process over the lifetime of the unit
- Process software extension / replacement:
    - Participating employee groups
    - Duration of an activity incl.
        - Configuration
        - Order processing

        - Installation at the user's desk
    - Amount of work per employee group
    - Costs of the software
    - Frequency of the process over the lifetime of the unit
- Process decommissioning:
    - Participating employee groups
    - Duration of an activity incl.
        - Collection at the user
        - Disassembly and disposal
        - Decommissioning documentation
    - Amount of work per employee group
    - Costs of the software
    - Frequency of the process over the lifetime of the unit

Operation-related processes

- Process service packs and patch installation:
    - Participating employee groups
    - Duration of an activity incl.
        - Configuration
        - Order processing
        - Installation at the user
    - Amount of work per employee group
    - Frequency of the process over the lifetime of the unit
- Process relocation:
    - Participating employee groups
    - Duration of an activity incl.
        - Disassembly
        - Transport
        - Assembly
        - Necessary configuration measures
    - Amount of work per employee group
    - Frequency of the process over the lifetime of the unit

In addition, factors such as general support costs and lost productivity due to self help of the user, and energy costs should be considered.

2.2.2 Economics

In order to determine the economics of a project, one has to contrast the costs with the expected benefits. This also means that an alternative has to be generated with which the planned project can be compared. The difficulty here is that one project scenario has to be chosen from the many possible applications of SBC which then has to be contrasted with a real or hypothetical alternative. On the one hand, this comparison has to be kept general so that it can be transferred to the reader's concrete project situations. On the other hand, it has to be concrete enough to assign costs and prices.

For this reason, the following assumptions are made for the subsequent evaluations:

- The business or institute plans the acquisition of workstation PCs for a large number of employees because the existing PCs do not meet the requirements of the applications to be used. In addition, the existing PCs have been depreciated completely.
- The business or institute is examining the possibility for long-term cost reductions. Short-term, large initial investments are possible.
- The average utilization period of the units is five years for both alternatives.
- The homogeneity of the requirements and the limited number of the necessary software packages for a large number of employees makes the use of SBC and Thin Clients an alternative.

2.2.3 Costs

When observing the costs, only those costs are taken into consideration that are relevant for both alternatives. In this sense, relevant costs include hardware costs or the individual support costs, whereas costs for the network infrastructure or cost for the support of the implemented software are irrelevant.

Under the given assumptions the cost for a centrally managed workstation PC for a number of 175 clients and the assumed utilization life of five years[1] would be **4,557.69 €**. The costs decrease to **2,781.62 €** when server based computing and thin clients are implemented, again given that 175 workstations have to be supported.

[1] Using the same utilization period enables better comparisons. A utilization period of three years for PCs tends to be more likely, whereas the utilization period of Thin Clients is significantly longer due to their independence from current hardware requirements of software packages on one hand and the lower failure rate based on the lack of parts that are subject to mechanical wear. The utilization period was defined as a calculatory value to make the operating model comparable with that of the Thin Client environment.

Number of users	Managed PC	Thin Client	Savings
35	2 728.55 €	1 587.35 €	41.82%
70	2 485.39 €	1 587.35 €	36.13%
105	2 404.33 €	1 587.35 €	33.98%
140	2 363.81 €	1 587.35 €	32.85%
175	2 339.49 €	1 587.35 €	32.15%
210	2 323.28 €	1 587.35 €	31.68%
245	2 311.70 €	1 587.35 €	31.33%
280	2 303.02 €	1 587.35 €	31.08%
315	2 296.26 €	1 587.35 €	30.87%
350	2 290.86 €	1 587.35 €	30.71%

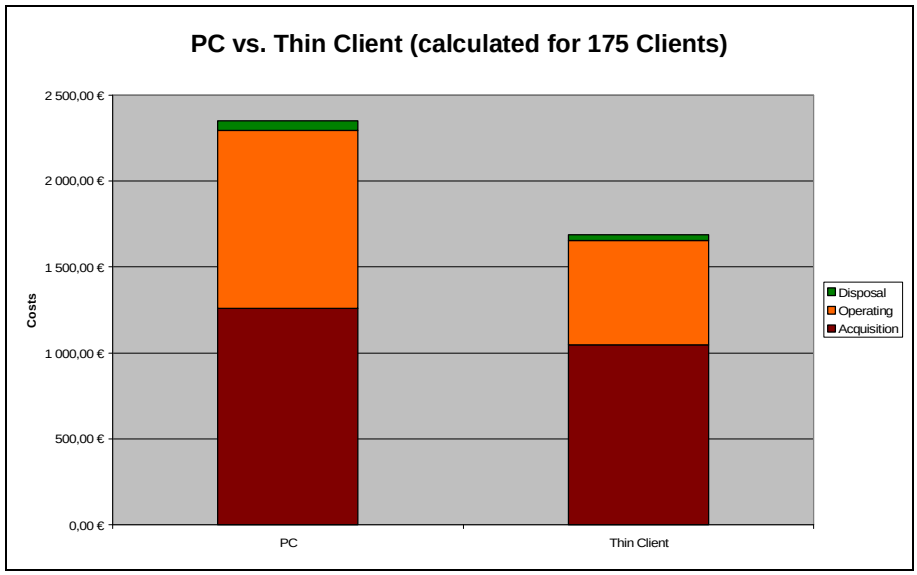
The above values contain the acquisition costs including the unit price as well as the operating costs. According to the cost model, 31-42 % could be saved per workstation with SBC. The concrete savings are dependent on several parameters, however.

Since Thin Clients share server resources, the fixed costs per server are spread over all Clients with the consequence that the individual workstation becomes less expensive the more Thin Clients are utilized. However, only a specific number of Clients can be served by the terminal server. If more users are to use the services of a terminal server, additional servers are necessary which would lead to the generation of fixed-step costs. The number of users per server was fixed to 35.

As explained in section 4, an additional reserve server should be provided in order to compensate for an unexpected outage of a server or to turn off a server for maintenance without stopping operation.

Number of users	Managed PC	Thin Client	Savings
35	2 728.55 €	2 089.51 €	23.42%
70	2 485.39 €	1 838.43 €	26.03%
105	2 404.33 €	1 754.74 €	27.02%
140	2 363.81 €	1 712.89 €	27.54%
175	2 339.49 €	1 687.78 €	27.86%
210	2 323.28 €	1 671.04 €	28.07%
245	2 311.70 €	1 659.09 €	28.23%
280	2 303.02 €	1 650.12 €	28.35%
315	2 296.26 €	1 643.14 €	28.44%
350	2 290.86 €	1 637.56 €	28.52%

Using the realistic mathematical model, **savings potentials of 23-29 %** are predicted compared to "managed PCs".



The cost models are based on model-like assumptions. Naturally, Fraunhofer UMSICHT offers additional consulting so that the individual models can be adapted to concrete project scenarios and varied accordingly.

2.2.4 Benefits

2.2.4.1 Quantitative benefits

Quantifiable benefit is created wherever the terminal server environment reduces costs that would have occured in direct connection with the operation of PCs. Here, the lower acquisition costs should be mentioned that are, however, only a small portion of the total costs as proven by the model calculations of Fraunhofer UMSICHT.

In addition, the majority of client-related personnel costs (only a small portion is assigned to the server side) such as initial installation, additional installation, replacement of defective parts potentially combined with reinstallation do not apply.

Personnel costs that arise on the user side during the life cycle of the workstation PC should also not be underestimated. According to the models, these costs account for 64 % of the total costs by employee groups. On the one hand, the enduser has to endure up to several hours without his computer during PC maintenance. On the other hand, in case of a server-side problem, the enduser can switch to another server and continue working right away given a well implemented terminal server. Defects on the Client can also be fixed immediately by simply replacing the unit.

2.2.4.2 Qualitative benefits

The regulation and standardization of a terminal server environment might be perceived as paternalism and unnecessary restriction, but rationally viewed it can be seen as a qualitative advantage. Fewer possibilities for self administration by the user also mean less opportunity for users to make their lives more difficult.

Depending on the business guidelines, missing or restricted access to local media such as diskettes, flash drives, or CD-ROMs lead to fewer opportunities for critical data to leave the business and also keeps out viruses and unauthorized programs, making the work environment more secure. This applies to malfunctions from faulty installations as well as legal problems that stem from the use of non-licensed software.

In addition, the provision of new software packages can be performed uniformly and significantly faster via a terminal server as the administration point, which benefits the enduser as well as the administrator.

As part of the innovation offensive OFFICE21, Fraunhofer IAO investigated which requirements a workstation has to meet in order to help the employee be most productive.

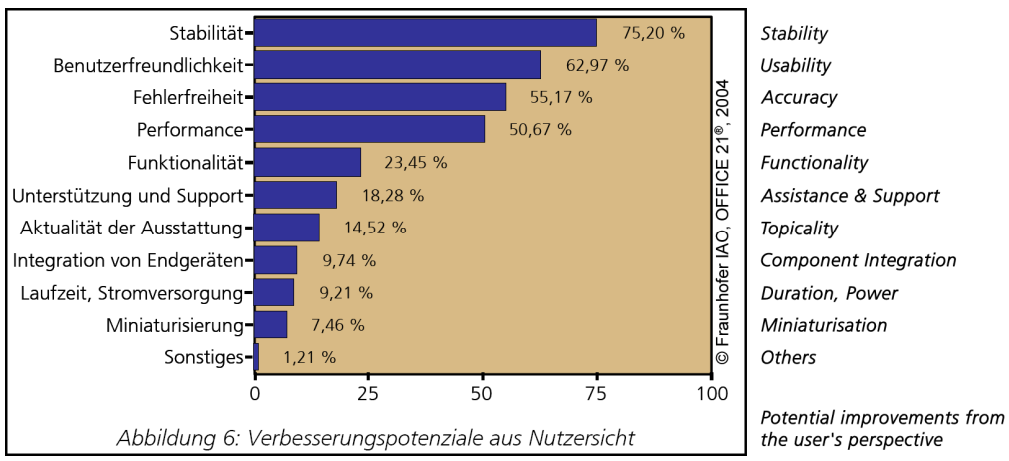


Abbildung 6: Verbesserungspotenziale aus Nutzersicht

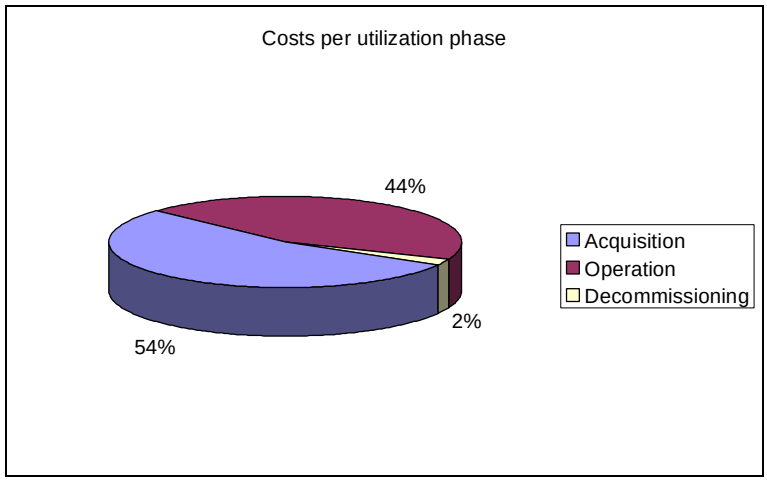
The study [IAO 2004] in which the results of the investigation are summarized clearly showed that the majority of the endusers value stability, accuracy, and performance for the acceptance of new technologies.

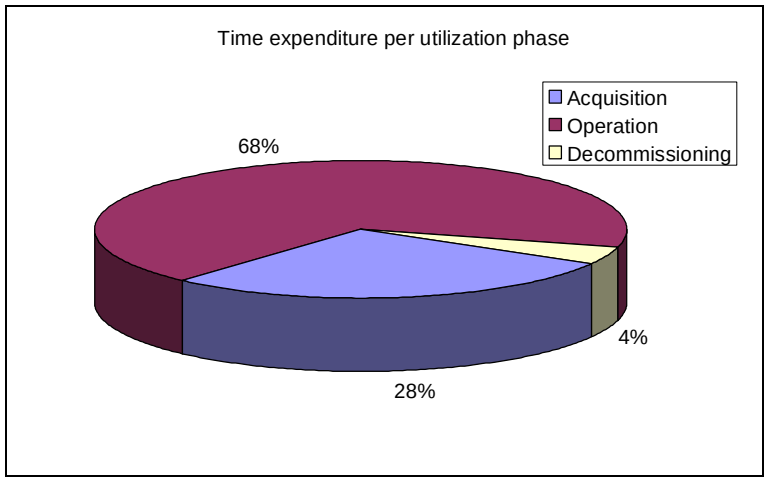
These are exactly the aspects in which the terminal server concept promises advantages compared to conventional workstation PCs. Certainly, no concessions have to be made regarding user friendliness –the second most

important aspect after all according to IAO - on a terminal server since the user is working with the familiar Windows® interface.

2.2.5 Result of the comparison

The central observation from the comparison under the consideration of only the technology-specific parameters shows that viewing acquisition costs alone is not adequate.



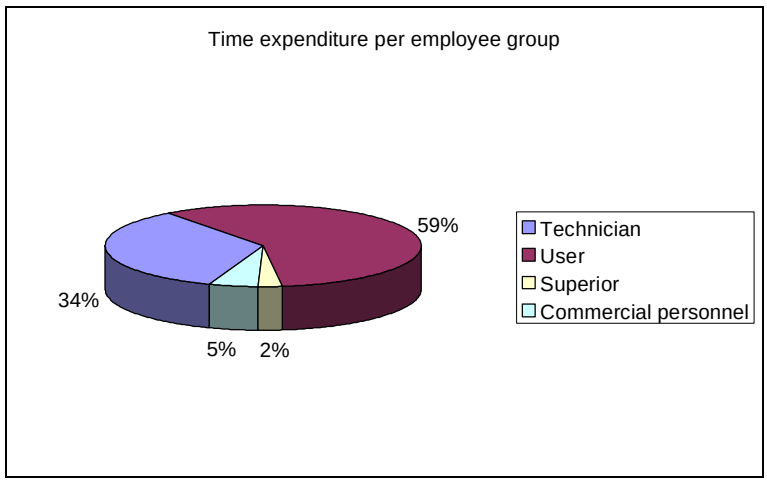


Both graphics refer to the "managed PC" model with an assumed 175 workstations to be supported.

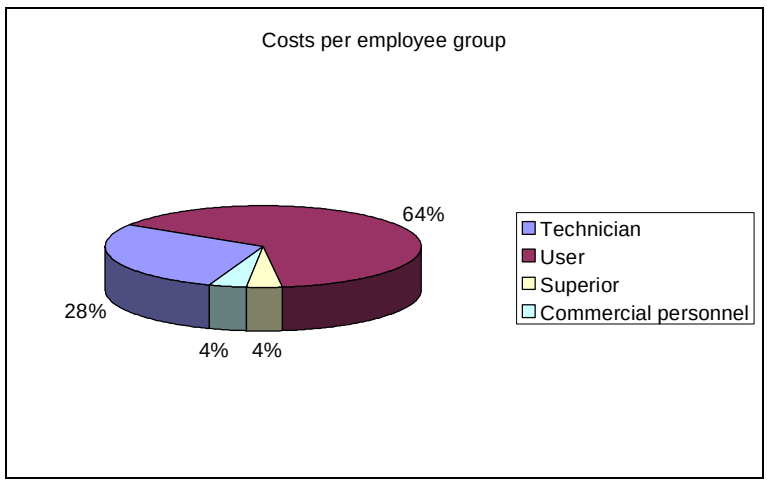
The acquisition costs account for 54 % of the total costs. If one looks at the time requirements alone, it can be seen that 68 % are incurred during the operating phase of the PC. This is also the phase during which the highest savings can be achieved. As a result, the initially high investment in a terminal

server work environment amortizes over the utilization life due to the lower operating costs.

If one breaks down the time requirements displayed above into employee groups, it can be seen that the time requirement is relatively high for the user with 59 % of the total. It should be noted that this is important from the view of the business management or institute regardless of the actual internal assessment of the economic evaluation.



Based on the different personnel costs for different employee groups, the cost-based portion for the user is actually 64 %.



In the context of cost reductions, it is advantageous to relieve the user from typical PC support as much as possible. That is where Server Based Computing

can make a significant contribution through standardization and by limiting the possibilities for "self-administration"[2] by the user.

2.2.6 Transfer into practice

Since all aspects of the generic point system are dependent on the nature of business internal processes and, therefore, subject to great variation from one company to the next, the calculations in the following chapter are based on assumed values from a modeled reference environment. Wherever assumptions were made, it is explicitly stated and explained.

In order to transfer the model calculations to a concrete situation, business-internal controlling mechanisms are necessary to deliver the required values. Therefore, a help-desk system has to have a reporting function for example so that support activities can be captured in terms of time requirements but also problem specific or according to the costs-by-cause principle. As explained in the cost models, certain activities exist that occur in undiminished numbers for the PC and the SBC concept. These have to be taken out of the calculations for the comparison.

Benchmarking as controlling method for the investigation of the said activities is often not established at all locations of a business, let alone in a uniform database. The establishment of ITIL-conformed processes can help create a reliable database but requires the availability of certain tools.

[2] In the cost model, the terms personal administration and self help encompass all expenditures that arise from the configuration of the workstation or the elimination of problems that the user performs himself.

3 Cost Model PC

3.1 Preface

If a business or institute has to determine their own TCO to create strategies for cost reduction such as the utilization of Server Based Computing, an investigation has to be performed to determine which costs are accrued in which organizational units. The necessary prerequisite for this to establish IT-controlling and benchmarking mechanisms.

If exact information about one's cost structure is not available and if there is no breakdown of the causes for costs, the determination of TCO is not possible. In order to avoid not having the necessary discussion about potential savings from Server Based Computing and Thin Client technology due to missing data or to only have it on a hypothetical level with purely qualitative arguments, a support construct - individual cost model - is necessary.

Following will be an individual cost model for the current prevalent use of workstation PCs adapted to a hypothetical but realistic reference model of an exemplary company. This model is primarily evaluated with regard to the implementation of Server Based Computing and Thin Client technology. Therefore, it does not focus on all costs and expenses that are associated with the operation of a workstation PC but only the ones that are relevant to the difference in Thin Client technology. For example, the costs for LAN infrastructure are not considered because they do not reveal any differences or savings potentials regarding the comparison of both technologies.

3.2 Database

The cost model is mainly based on:

- A survey with a questionnaire given to the IT-Management of the Fraunhofer Institute for Environmental, Safety, and Energy Technology UMSICHT in Oberhausen

- Personal observations and experiences from the area of IT support and the acquisition planning of several large and medium-sized businesses

3.3 Assumptions

In order to make cost statements based on measured or estimated time expenditures, the respective times will be assigned to the following employee groups. Specific, annual personnel costs will be assumed for each employee group.

Employee group	Personnel costs/year
Technician	65,000 €
User	84,000 €
Supervisor	115,000 €
Purchasing manager	60,000 €

Furthermore, it is assumed that the average work time is 166 hours per month.

The first cost model includes the following assumptions:

- Cost for infrastructure such as LAN-wiring, switches, routers and central network services are not considered.
- Overhead such as rent, insurance, safety services, etc. are not considered.
- The following activities will be considered in the life cycle of the PC:
    - Initial acquisition
    - 1 hardware upgrade or replacement purchase
    - Software purchase according to the standard of the initial installation
    - 2 software purchases outside of the standard of the initial installation
    - Active patch management
    - Proper decommissioning
- A PC is used for five years.
- All values are averages.
- The costs for the purchase of periphery equipment such as printers or monitors are not considered since they would not have a significant influence on the costs of switching to Thin Clients and Server Based Computing.

Validity of the assumptions

All assumed values including the life of the PC, travel, acquisition costs of the PC, or the personnel costs can vary from one company to the next. These numbers can be replaced by more accurate numbers when using the model to evaluate a specific project. This does not change the general applicability of the model as such.

Furthermore, the assumptions are valid only for employees whose work and investigations do not focus directly or mainly on IT generally, or on hardware or software themselves. This includes especially employees in administration, documentation, or other positions with general office activity.

3.4 Objective of the evaluation

The following expenses will be evaluated:

Acquisition costs
- Configuration
- Order processing
- Initial installation
- Rollout to the user
- Software licenses
- Purchase price of the hardware

Operating costs
- Support
- Service pack and patch installation
- Software installation
- Hardware installation
- Self-help of the user
- Relocation costs
- Energy costs

Decommissioning
- Software uninstallation
- Disassembly and disposal

3.4.1 Acquisition

3.4.1.1 Configuration

With a new or upgrade purchases of hardware and software, it should be investigated which specific requirements this workstation has and which sale offers can be taken advantage of in the market to fulfill them inexpensively. Questions to be answered are whether particular parts of the existing hardware such as expensive data acquisition boards, existing printers, etc. can be transferred or which modules can be used for a memory upgrade.

Prior to the purchase of software, it should be checked whether the PC on which the software is to be used meets the minimum requirements for the software.

These activities fall under the term configuration.

The continuous use of standard product portfolio with pre-defined performance classes and computer standards as well as an inventory database are a necessary prerequisite for this. However, an expense that should not be underestimated is generated by the collection and management of the data.

Calculation model

It is assumed that in addition to the initial purchase each PC will require one hardware purchase, two software purchases outside of the standard, and four software purchases within the standard during its entire life cycle.

It is also assumed that purchase activities made up of research and compilation of all necessary information take 5 minutes. The initial purchase takes 10 minutes, however.

Activity	Time expenditure per activity	Execution
Initial purchase	10 min	Technician
Hardware upgrade/replacement	5 min	Technician
Software purchase	5 min	Technician

Description	Time expenditure per PC	Execution
Configuration	45 min	Technician

3.4.1.2 Order processing

The processing of the order has to be authorized by the superior or cost center manager first. Upon the authorization, the implementation follows by obtaining a concrete quote and the transfer of the document to the purchasing department. The purchasing department issues the contract to the dealer. In total, at least three persons are usually involved in this process.

Calculation model

It can be assumed that each step in this process takes about 5 minutes. Obtaining quotes for hardware can require a greater amount of time of up to 15 minutes. This includes the administrative tasks of each step such as copying, scanning, and filing.

Activity	Time expenditure per activity	Execution
Authorization	10 min	Supervisor
Obtaining quote hardware	15 min	Technician
or obtaining quote software	5 min	Technician
Contract processing	15 min	Purchasing manager

Based on the assumption that three additional purchases will be made aside from the initial purchase (total 2x hardware + 2x software), the following list results:

Description	Time expenditure per PC	Execution
Order processing	40 min	Supervisor
Order processing	40 min	Technician
Order processing	60 min	Purchasing manager

3.4.1.3 Initial installation

Typical tasks that are assigned to initial installation are the reception of the delivery, the inspection of the packing list, and the amendment of the process documents. Subsequently, the operating system including all necessary drivers and standard software (Office, Acrobat Reader, WinZip, service packs,etc.) have to be installed.

The time expenditure for this procedure is greatly dependent on the method used for the automatic software distribution on one hand and the ability to standardize the installation based on different hardware and their required drivers on the other hand. Generally, the costs can be significantly reduced through automatic software distribution. However, potential savings are dependent on the frequency with which the specially prepared installation packages are used in relation to the effort of their creation. Additionally, costs are accrued for the provision of a software distribution solution in general.

Aside from the technical aspect, inventory lists with serial numbers, part descriptions and equipment characteristics, and licenses have to be managed in corresponding lists and databases. This information administration is similarly necessary in the ERP-system as it is for the IT-management due to the different data management.

Calculation model

It is assumed that the reception of the delivery requires 15 minutes, as does the upkeep of inventory lists and licenses. If a software distribution system is utilized, the technician only requires about fifteen minutes to control and supervise the process of installation.

Activity	Time expenditure per activity	Execution
Delivery reception	15 min	Technician
Standard installation	15 min	Technician
Update inventories and licenses	15 min	Technician
Update inventories and licenses	10 min	Purchasing manager

Description	Time expenditure per PC	Execution
Initial installation	45 min	Technician
Initial installation	10 min	Purchasing manager

3.4.1.4 Rollout to the user

The configured PC or the purchased software has to be put into operation at the workstation of the enduser. Typical tasks for this activity are the appointment coordination, transportation to the workstation, disassembly of the old system, and the erection and connection of the new system or the installation and transfer to the enduser.

Additionally, personal data has to be secured previously and later transferred to the new system, and the desktop has to be configured to personal preferences which is usually performed by the enduser. Despite a central memory management with centrally stored profiles and the guideline not to store data locally, practice shows time and time again that data is still locally saved even just as a "personal security concept" by manually backing up the data to a central fileserver every evening. Additional efforts based on potential training or the salvaging of hardware from an old system was not considered.

Calculation model

Assuming that the workstation of the enduser and the IT management are in the same location, the travel time is presumed to be five minutes. Furthermore, the user is present during the erection of the new unit. The disassembly of the old unit as well as the connection of the new unit will require 20 minutes. The transfer of the unit will take 15 minutes as does transporting the old unit away. The final user will take 40 minutes for transferring old data, and configuring the unit combined with making himself familiar with it.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Missed work for securing personal data	20 min	User
Transport to the workstation	5 min	Technician
Disassembly of old unit	10 min	Technician
Missed work due to disassembly of old unit	10 min	User
Missed work due to assembly of new unit	10 min	User

Assembly new unit	10 min	Technician
Missed work due to assembly of new unit	10 min	User
Transfer	15 min	Technician
Transfer	15 min	User
Transporting old unit away	5 min	Technician
Transfer data and individual configuration	40 min	User

Description	Time expenditure per PC	Execution
Rollout to the user	35 min	Technician
Rollout to the user	125 min	User

3.4.1.5 Software licenses

In order to determine total license costs for a workstation PC, the relevant inventory documents have to be evaluated and data on the value of the licensed software has to be compiled.

However, it should be expected that the accrued license costs will stay largely the same if the standard software is used via Server Based Computing. Therefore, the absolute license costs are irrelevant for this model since these are not licenses that are needed only for Server Based Computing (e.g. Citrix® licenses).

Thus, software licenses for application programs were not included in this cost model.

3.4.1.6 Purchase price of the hardware

Based on the current market situation, about 650 € should be estimated for a sustainable standard workstation.

Hardware purchase costs accumulate even during the utilization period of five years. These could be for replacements for defective parts that do not have a warranty anymore or for parts to increase the performance of the computer.

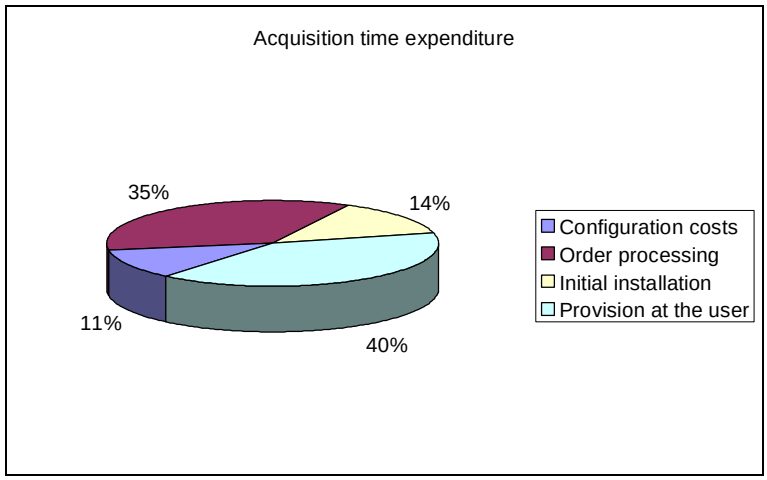
Description	Costs per PC
Costs initial purchase	650 €
Costs upgrade/replacement purchase	150 €

Additionally license cost for the operating system, a Microsoft server client access license (CAL) and a client license for the software deployment system have to be considered. Starting from a number of five clients discount prices according to the Microsoft Open License Program are available.

Bezeichnung	Kosten pro PC
Microsoft Windows Vista Enterprise	140 €
Microsoft Windows Server 2003 Device CAL	20 €
Lizenz Softwaremanagementsystem	50 €

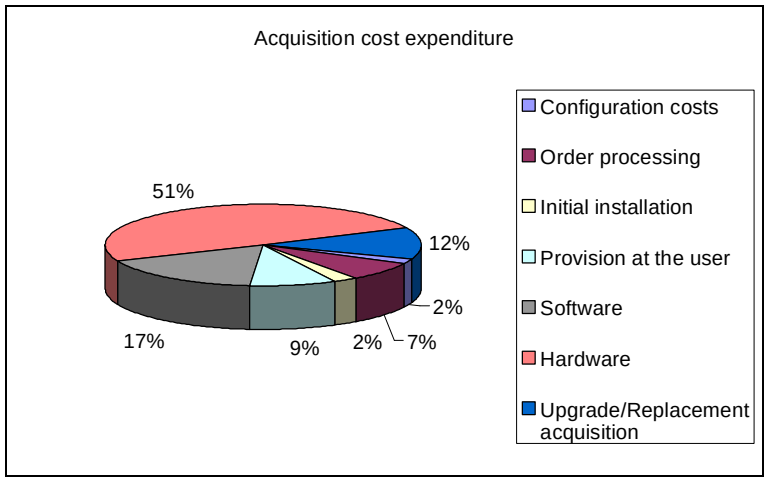
3.4.1.7 Evaluation acquisition

The following graph shows the distribution of the time requirements during the acquisition.

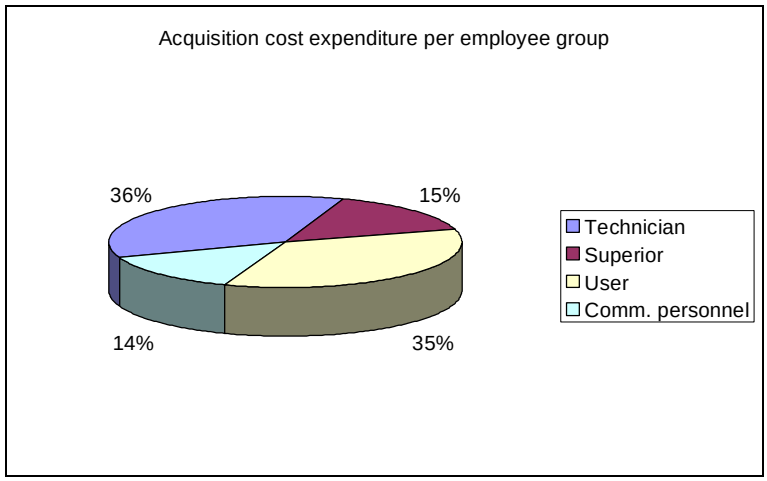


Activity	Time Expenditure
Configuration	45 min
Order processing	140 min
Initial installation	55 min
Rollout to the user	160 min
Total	**400 min**

About half of the costs are accounted for by hardware.



The IT department only accounts for approx. one third of the labour costs.



3.4.2 Operating costs

3.4.2.1 Support

The term support encompasses all functions that are necessary for the upkeep or reestablishment of the full functionality of the workstation PC. This includes supporting the user with questions regarding the software use as part of the help desk, the elimination of malfunctions on the workstation PC or periphery units, resetting of passwords, and many more tasks.

In the context of a comparison with Thin Client technology, it is sensible to evaluate specific malfunctions at a workstation which influence the support costs.

Hardware malfunction with hard drives

A PC usually contains moving, mechanical components in the form of drives and fans. Hard drives should be mentioned especially in this context. They rotate at speed of up to 5 400 rpm or 7 200 rpm on desktops and are, therefore, subject to mechanical wear. Hard drive malfunctions are associated with significant work losses and support requirements. The user cannot work on his PC initially, data could be lost permanently and might have to be recreated if possible.

The IT management will have additional tasks in such a case. In addition to the installation of a new hard drive, the reinstallation of the operating system, drivers, software packages, necessary patches, and service packs have to be performed. This means that previously completed activities have to be repeated.

A similar scenario occurs with power supply units which are also subject to wear. This can lead to the breakdown of the PC, the need for replacement, and most of all work losses.

The actual loss rate depends greatly on the quality of the components, the manufacturer, the handling, the environment, and coincidence. Even name-brand manufacturers are not immune to having product series with higher failure rates. If a large number of these susceptible components were purchased during high market presence, the failure rates can vary by more than 500 %.

Therefore, the cost model uses the simplified assumption that a hardware purchase is necessary for every PC and a complete reinstallation is necessary for every other PC during the utilization period. The hardware acquisition assumption is irrespective of whether it is due to a failure or for a performance or functionality upgrade. However, this does not represent a failure rate of 100 %. Rather, a more realistic failure rate is appr. 2 % - 5 %. Conversely, it can be assumed that almost every PC will require an upgrade or a complete reinstallation during its life cycle. This is also a result of the comparatively long (calculatory) utilization period of five years.

3.4.2.2 Installation of service packs and patches

Unfortunately, day to day practice has shown that modern software is susceptible to errors. Many of these errors such as in browsers, email and application programs, and in the operating system Windows® do not only frustrate or reduce productivity due to crashes but also represent very serious security gaps. That is why it is of great importance to install patches, service packs, and program updates in a timely manner despite central protection

mechanisms such as firewalls, virus scanners, etc. It is important to emphasize that potential threats not only exist from the network but also from data carrier exchange via local drives or the commissioning of an unprotected notebook from an external employee.

The experience with automated patch management shows that expenditures in the IT department on the client side decrease (the server side costs are evaluated in a later chapter). However, two problems remain: Only workstation PCs that are regularly operated in LAN can be automatically patched, and automatically installed patches mostly require a restart of the system disturbing the work of the user.

Activity	Time expenditure per activity	Execution
Patch installation	0 min	Technician
Patch installation	5 min	User

Assuming that after the introduction of the so-called Patch-Day from Microsoft which would require one restart per month, the following time efforts will be needed per workstation and PC for patch activities over the utilization period of five years.

Activity	Time expenditure per PC	Execution
Patch installation	0 min	Technician
Patch installation	300 min	User

Comments on the calculation model

It is assumed that patches will be tested before the automated installation in order to avoid additional, unplanned downtime caused by faulty patches. The distribution of anti virus patterns occurs unnoticed by the user.

3.4.2.3 Software installation

The individual installation of software becomes necessary when the specific software is purchased and needs to be utilized at the workstation of a user. The installation is usually performed by IT management. This is necessary because the user does not have the necessary administrative authorization among other things.

There is a good reason why only the employees of the IT department have the authorization to install software on a workstation. Although these measures are often disliked and seen as paternalistic by the users, it is the only way to prevent unwanted software installation and, as a result, insufficient licensing or the distribution of unwanted software.

Calculation model

The frequency and the individual time expenditure for the installation of software is dependent on the requirements of the specific workstation as well as the software itself and is, therefore, highly variable.

It is assumed in this cost model that a total of six software packages such as a new Office, a new Adobe Reader Version, etc. are installed per PC over its lifecycle. This does not include service packs, patches or updates. Rather, new versions of application programs are meant that are not available at the time of the initial installation and, therefore, have to be installed separately.

As opposed to the distribution of patches, the time expenditure of the technician does not fall away completely because installation packages have to be assigned prior to distribution and license and inventory information has to be managed.

Activity	Time expenditure per activity	Execution
Preparation	5 min	Technician
Work loss during installation	5 min	User
Postprocessing	7 min	Technician

Six installations over five years:

Activity	Time expenditure per PC	Execution
Software installation	72 min	Technician
Software installation	30 min	User

3.4.2.4 Hardware installation

An individual hardware installation is always necessary when a part of the original hardware has to be replaced due to failure or to upgrade the PC to increase the performance or functionality. Such hardware upgrades could be a larger hard drive, a new CD-ROM/DVD drive, a larger RAM, etc. These tasks are usually performed by an employee of the IT department because they have the necessary training to do them.

Calculation model

It is assumed that one hardware installation is necessary per PC during their utilization period. This covers the purchase of replacements for defective parts as well as new parts.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Preparation	3 min	Technician
Travel time to workstation	5 min	Technician
Installation of the hardware	25 min	Technician
Work loss during the installation	25 min	User
Return travel time	5 min	Technician
Postprocessing	5 min	Technician

Activity	Time expenditure per PC	Execution
Hardware installation	48 min	Technician
Hardware installation	30 min	User

Based on the nature of the activity, automation is not an option here and manual installation is always necessary.

3.4.2.5 Relocation

The employees of the IT department accompany the relocation of the user. This can occur in various ways. In every case, it has to be ensured that the PC of the user can still be used in the network of the institute. In order to accomplish this for VLANS for example, the assignment of the ports has to be updated on the switch.

In addition, IT departments sometimes offer the users the service to disassemble, transport, and reassemble the PC at the new work place.

Calculation model

It is assumed that a workstation PC is moved once in five years. Local investigations on this topic revealed a frequency of 1.5x, but these values should not be representative.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Travel time to the workstation	5 min	Technician
Completion	60 min	Technician
Work loss	60 min	User
Return travel time	5 min	Technician
Updating inventory	5 min	Technician

Activity	Time expenditure per PC	Execution
Hardware installation	80 min	Technician
Hardware installation	65 min	User

This process also does not lend itself to automation or should not be performed by the user.

3.4.2.6 Reinstallation

A reinstallation is always necessary when the functionality of the workstation is greatly reduced or working has become impossible. This could be due to hardware malfunctions, also defects on the local hard drive especially, or due to unsuccessful software installations and updates.

Additionally, when a new operating system is to be used, it is equivalent to a reinstallation in terms of the time expenditure.

A reinstallation can also be used to reset a system to a defined initial state and to reverse numerous, previous software installations that do not uninstall easily or that led to corrupt registry database.

The tasks to be completed are primarily the provision of the PC. Additionally, the software packages including patches used by the user have to be installed.

Calculation model

On average, about 10 % of workstation PCs are newly installed every year. This represents 50 % for a utilization period of five years. Under consideration of automatic software deployment possibilities, the following picture arises.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Preparation	5 min	Technician
Standard installation	15 min	Technician
Work loss during installation	180 min	User
Postprocessing	7 min	Technician

Total amount over five years:

Activity	Time expenditure per PC	Execution
Reinstallation	16 min	Technician
Reinstallation	93 min	User

3.4.2.7 Personal administration and self help

In this cost model, the terms personal administration and self help stand for all the activities that relate to the configuration of the workstation or the elimination of problems by the user himself.

Whether it is the configuration of the desktop or the self help with solving a problem, users seek to solve smaller problems based on their private experience with PCs and to support their colleagues with it.

In the USA, the term "Hey Joe Support" was coined to describe that. When a user has a problem with their PC, they usually ask their colleague "Joe" for support first.

Although this approach may be commendable and practical in some cases, it is crucial to view it in a greater context and from the perspective of the business. It is possible that self help attempts create more damage than was originally caused by the problem. As a result, the actual diagnosis or analysis can be more difficult for a technician and the employees are not doing what they were hired for. Even if they solve the problem themselves, the experience is not recorded in a central database. If the problem occurred again, it might not be identified as such and the possibilities for a centralized solution are hindered.

For IT departments, it is also only a seeming advantage. A short-term personnel relief is countered by long-term frustration and rejection from the user.

This problem cannot be solved with Thin Client technology alone. In addition, fast and competent help from the official support on one hand and "educational" measures on the other hand are needed. Regarding this problem, Thin Client technology does, however, take away the opportunity for the user to grab a screwdriver and try to solve a hardware problem as opposed to workstation PCs.

Calculation model

It is assumed that on average a user spends about five minutes per month to change the configuration of his workstation PC, solve local problems, install programs (drivers, patches), or make alterations on the hardware (e.g. BIOS or firmware updates).

When evaluating the value of five minutes per PC it should be noted that there are many users that use their PC over weeks or months without any problems or need for support. As a rule, there are a few number of "Power User" or persons with higher support needs that can spend hours on end several times to try to solve assumed or actual problems. Depending on the institute, the

number of such persons and the duration of the self help can vary greatly. Therefore, the five minutes are an attempt to define a realistic average value.

An additional complication for the determination of such an average value lies in the fact that the distinction whether a problem is associated with the workstation itself or with the software alone is often difficult. The question to be asked is: Would the same problem occur if the same software environment was on a terminal server? A measurement is not possible because it is about self help of the user so that these cases are not recorded or evaluated by the service desk.

Activity	Time expenditure per activity	Execution
Self help	5 min	User

Total amount over five years:

Activity	Time expenditure per PC	Execution
Self help	300 min	User

The projection over the five year time frame results in 300 minutes that are lost per user or workstation. This is independent of the question whether automated software distribution is used or not.

3.4.2.8 Energy costs

As with any electronic device, the workstation PC also uses electricity during its operation. The more modern the PC, the more powerful it is but also the more energy it requires. Energy consumption and ecological aspects of PC and thin clients are discussed in separate study issued by Fraunhofer UMSICHT [UMSICHT 2008].

Calculation model

Within the scope of this study it is assumed that a PC requires 90 watts when running ("idle") and 2,5 watts when switched off ("soft-off"). When the PC is shut down after work this makes up an average of 35 watts over 24 hours. However it is assumed that one third of all PC is not turned off at all. The calculation is based on 220 working days per year.

	Working days per year	Watt	Costs (5 Years)
PC (shut down)			
Energy costs (working)	220	35	138.60 €
Energy costs (remaining time)	145	2,5	6.53 €
PC (running all time)			
Energy costs (working)	220	90	356.40 €
Energy costs (remaining time)	145	90	234.90 €

Average total amount over five years:

Description	Kosten pro PC
Energy costs (average)	293.85 €

3.4.2.9 Operation evaluation

The table shows the costs for the operation.

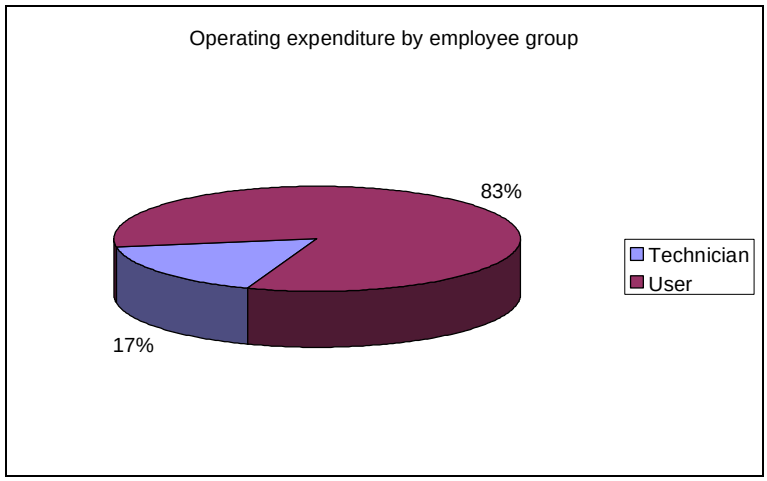
Description	Costs
Software installation	60.24 €
Patch installation	210.84 €
Hardware installation	47.19 €
Relocation	89.19 €
Reinstallation	73.71 €
Self help	210.84 €
Energy costs	293.85 €
Total	**985.87 €**

The table shows the time expenditure for each activity.

Description	Time expenditure
Software installation	102 min
Patch installation	300 min
Hardware installation	78 min
Relocation	145 min
Reinstallation	109 min
Self help	300 min
Total	**1 034 min**

The evaluation of the expenses for automated installation per employee group shows that the user or his cost center carry over 80 % of the costs that are typically associated with the operation of a workstation PC. These costs are not the consequence of accounting for services, but are largely indirect costs. The

main portion of the expenditures of the user are losses in productivity caused by the waiting period during software and patch installation.



Employee group	Costs
Technician	117.47 €
User	574.55 €

3.4.3 Decommissioning

At the end of the utilization period, a PC is disassembled at the workstation of the user, decommissioned, and disposed of. Based on the assumed utilization period of five years and the associated, increased hardware failure risk, a reuse of the complete unit is not considered.

Various tasks are associated with the decommissioning. First, inventory data regarding the unit have to be updated. In addition, the utilized licenses have to be updated in the corresponding lists.

Another aspect is the processing of the official decommissioning documentation which has to be processed by the IT department as well as the purchasing department.

Regarding the disposal, it has to be ensured that potential remaining data on the unit have to be definitely and irreversibly erased. Simply deleting the data or formatting of the hard drive with the tools of the operating system are not sufficiently safe for this and do not prevent the manual reconstruction and recovery of the original data.The hard drive has to be rewritten several times with bit patterns that ensure that every bit on the hard drive is definitely changed.

Additionally, periphery equipment such as cards or components that still make sense to be used in other PCs should be removed from the unit prior to the final scrapping. Aside from expensive data acquisition boards, other reusable components can be retained as replacement parts.

Calculation model

The formatting of the hard drive takes several hours with the support program of the BSI[3]. Since the process does not have to be monitored the whole time, only ten minutes will be assigned in the cost model.

The PCs that are to be disposed of have to be stored. A time requirement of ten minutes per PC is calculated for this.

Activity	Time expenditure per activity	Execution
Inventory list updating	10 min	Technician
Hard drive formatting	10 min	Technician
Decommissioning documentation	10 min	Technician
Decommissioning documentation	10 min	Purchasing manager
Disassembly	15 min	Technician
Storage	10 min	Technician

Description	Time expenditure per PC	Execution
Decommissioning	55 min	Technician
Decommissioning	10 min	Purchasing manager

Added to that are the disposal costs for the electronic scrap which is currently paid based on weight. A cost of 25 € per PC is assumed for this cost model.

Description	Costs per PC	
Disposal costs	25 €	-

3.4.4 Server-side costs

When using automatic software deployment a management server is needed and has to be apportioned to the clients. The following cost components are considered:

Purchasing costs
- Configuration
- Order processing

[3] The Federal Office for Information Security (BSI) is the central IT security service provider for the German government (http://www.bsi.bund.de). It has released a program to securely erase hard disks and other storage media.

- Initial installation
- Software licenses
- Purchase price of the hardware

Operating costs
- Support, supervision
- Time expenditure for scripting or package design for
  - Operating systems
  - Drivers
  - Applications
- Support requirements (maintenance and regular inspection) for the distribution of
  - Patches
  - Anti virus patterns
- Energy costs

Decommissioning
- Software uninstallation
- Disassembly and scrapping

3.4.4.1 Assumptions of the cost model

The following assumptions are made for the server-side costs:

- Costs for the infrastructure such as LAN wiring, switches, router, and central network services are not considered.
- Overhead costs such as rent, insurances, security service, etc. are not considered.
- One server with adequately powerful hardware and local support is implemented.
- All values are average values.
- Windows Server™ 2003 R2 Standard Edition is the utilized operating system.
- The software distribution is accomplished via Microsoft SMS or a comparable solution.
- The patch distribution is accomplished via the Microsoft® Windows® Software Update Services (WSUS).

3.4.4.2 Acquisition

3.4.4.2.1 Configuration

In this context, the configuration is the process of determining the requirements and specifications for a new server that is to be purchased. One of the initial tasks is server sizing. Since only one server is used for the software

distribution in our scenario, it has to be laid out very fail-safe by using redundant power supply and a RAID system for example.

Several quotes have to be requested from the market. The determined boundary conditions or product specifications have to be transferred to several suppliers and the received offers have to be compared and evaluated. The best offer then has to be presented to be authorized.

As opposed to the acquisition of workstation PCs or Thin Clients, the obtaining of offers is deliberately moved into this phase because it is a very closely related process to the server sizing which might have to be repeated iteratively.

Calculation model

Activity	Time expenditure per activity	Execution
Server sizing	15 min	Technician
Obtaining offers	15 min	Technician
Evaluating offers	15 min	Technician

Total amount:

Description	Time expenditure per server	Execution
Configuration	45 min	Technician

3.4.4.2.2 Order processing

The acquisition of a server first requires the authorization from a superior or a cost center officer which is usually the head of the IT department. Following the authorization, the documentation is transferred to the purchasing department and the supplier is contracted.

Calculation model

Description	Time expenditure per server	Execution
Authorization	10 min	Supervisors
Contract processing	15 min	Purchasing managers

3.4.4.2.3 Initial installation

The first aspect of the initial installation encompasses the reception of the delivery, the inspection of the packing list, and the subsequent assembly of the server in a 19" rack. Additionally, it includes the installation of an operating system including the necessary drivers, the current service packs and patches,

and the configuration of the services necessary for the software distribution. Finally, all relevant service packs, patches and hotfixes are installed for the server's operating system.

The packing list and other purchase documentation are transferred to the relevant department and the data is entered in the inventory lists and the ERP system.

Calculation model

The assembly and the basic installation of the operating system take about six hours. Added to that are the subsequent installation of the software distribution mechanisms and the provision of the operating system, drivers, and application for the support of a standard workstation.

It is assumed that the basic knowledge of how to configure the services and applications is well known from prior research and documentation. Nevertheless, the time expenditure for adapting the operating system to the specific client hardware including the integration of all drivers should not be underestimated.

Based on the experiences from the survey on the introduction of the software distribution solution at Fraunhofer UMSICHT, it is assumed that less than one man-month will be necessary at the beginning of the software distribution. In order to simplify, the expenditure is included only once.

Activity	Time expenditure per activity	Execution
Delivery reception	15 min	Technician
Basic installation incl. assembly	360 min	Technician
Install and configure services, script applications	9,360 min	Technician
Inventory and license management	15 min	Technician
Inventory and license management	10 min	Purchasing manager

Description	Time expenditure per server	Execution
Initial installation	9,750 min	Technician
Initial installation	10 min	Purchasing manager

3.4.4.2.4 Software licenses

Microsoft Windows Server™ 2003 R2 Standard Edition is installed on the server. Microsoft® Windows® Software Update Services are available at no charge. We assume that the software deployment solution is licensed per client.

Software	Costs
Windows Server™ 2003 R2 Std. Edition	475.00 €

3.4.4.2.5 Purchasing price

Because the deployment server is only used periodically the requirements regarding processor speed are rather low. The system must at least provide enough space for all installation packages. A server with one processor, 2 GB RAM and 300 GB hard disk space in RAID 5 configuration is considered with a purchace price of approx. **2 500 €**.

3.4.4.3 Evaluation of the acquisition costs

Description	Time expenditure	Costs
Configuration	45 min	24.47 €
Order processing	25 min	12.55 €
Initial installation incl. scripting	9 760 min	5 307.48 €
Software licenses		475.00 €
Hardware		2 500.00 €
Total	**9 803 min**	**8 319.50 €**

Therefore, the purchasing costs of the management server total 8 319,50 € including initial setup for the distribution of operating system, drivers, and applications.

3.4.4.4 Operation

3.4.4.4.1 Support

The support of the server encompasses the security, supervision, or the restoration of full functionality. The specific tasks include the supervision of event logs, the measurement and evaluation of performance and operational parameters such as the CPU load, main memory utilization, free memory, etc. Additionally, hardware-related parameters such as temperature and status messages of individual components have to be supervised and checked regularly. These tasks can be described with the term server monitoring and can be accomplished in a time-effective and efficient manner with tools such as LANrunner® for example.

The administrator only has to intervene when the values deviate from the normal, expected ones such as during hardware failures, error messages in the event log, or analog application-specific log files, low memory space, etc. In the case of hardware failures, the contract partner is informed and the fulfillment of the services is supervised assuming an appropriate maintenance contract.

Calculation model

The time requirements for the said tasks are mainly dependent on the support from the implemented management tools. It is assumed for this cost model that a quality solution is utilized and that the server requires an average of 30 minutes of support and administration per week. Considering 52 weeks for a five-year utilization period, the support requirement totals 7,800 minutes.

Activity	Time expenditure per week	Execution
Server support	30 min	Technician

Activity	Time expenditure per server	Execution
Server support	7 800 min	Technician

3.4.4.4.2 Installation of service packs and patches

Naturally, the installation of service packs and patches is necessary for the operating system and the services of the management server have to be considered. It is necessary to install all of the patches and updates provided by the manufacturer. This is especially important for all security-related updates.

Calculation model

The installation of patches encompasses preparation, the installation itself, and postprocessing (e.g. entering the executed steps into a server log).

Activity	Time expenditure per activity	Execution
Installation preparation	15 min	Technician
Installation of the service packs of patches	15 min	Technician
Postprocessing	10 min	Technician

Based on a five year utilization time, it is assumed that 60 planned installations will be performed every month. If a patch needs to be installed so quickly that waiting until the next planned downtime or to the end of the workday is not possible, an unscheduled installation has to be performed. It is assumed that this kind of additional installation of a patch or service pack occurs only about once a year.

Activity	Time expenditure per activity	Execution
Patch installation	2 600 min	Technician

Therefore, a total of 65 installation events are assumed. No distinction is made between planned or unplanned events because the maintenance of the management server does not directly influence the work of the user.

3.4.4.4.3 Additional packaging of software

If software that is to be installed is not yet known, it has to be evaluated and subsequently newly scripted.

The evaluation process is to clear whether and how to script the software, how to install it, and which requirements have to be met regarding the CPU, RAM, and hard drive for its regular operation. Generally, this necessitates research with the manufacturer, in the white papers of the software, and a test installation.

Such an evaluation is necessary once for every version of the software and in exceptional cases for significant changes in the management software. The time expenditure for such an evaluation process are known based on experience values and deducted from the experience of the IT department of Fraunhofer UMSICHT.

Activity	Time expenditure per activity	Execution
Research	60 min	Technician
Scripting and test installation	240 min	Technician
Documentation of the results	60 min	Technician

However, these specific values are very dependent on the individual experience of particular employees that are very knowledgeable with scripting and installing applications. It should, therefore, be verified whether the values can be arbitrarily transferred to other institutes or businesses. If the appropriate experience does not exist, the time expenditure could easily increase by a factor of ten. A questionnaire for the development of a database can be found in the appendix of this document.

In addition to the time expenditure, the costs for the necessary, dedicated test hardware on which the test installation can be performed have to be considered. The amount of the costs for this hardware and the licenses for the test environment and how they should be assigned to the specific evaluation and each workstation are currently unclear.

It is also unclear how the costs of the evaluation process should be assessed and how they should be allocated to individual PCs, departments, or institutes. Neither the use of costs-by-cause principle, nor a general allocation would be appropriate in the context of this cost model or would lead to sensible results.

The costs per workstation would mainly depend on how much software needs to be evaluated and then at how many workstations it will be used. This might even be difficult to calculate on an institute-level because the number of users can change later. Since the results of an evaluation should be centrally collected and generated to be available to all institutes, it could theoretically result in a decrease of the calculated costs because other institutes are using them as well. An allocation of the costs to the first user of this software also does not meet the goal of an appropriate cost distribution because as long as no internal service accounting between the departments and the IT-department on one hand and between departments of different institutes on the other hand the IT departments that perform the evaluation can only sit on the costs. Conversely, the people who wait with the evaluation will be better off – maybe someone else will do it. The continuation of this thought leads to IT departments refraining from using software that requires evaluation and, as a result, to refrain from a consistent use of software distribution. This development has to be avoided. Therefore, it is suggested to find a central, institute internal, and institute-to-institute, practical solution as was the case with the creation of the service center for the CCM topic.

This expenditure for the evaluation, scripting, and test installation only accrues once, however. In order to determine the proportional costs for software installation per workstation, it has to be resolved how many different software packages have to be installed total in each case.

It cannot be assumed that 150 workstations, which require two software packages each outside of the standard product portfolio, result in 300 different software installations. The question how many finished, scripted programs can simply be assigned to an installation package and be made available to a group and how many different installations are still necessary after that is not easy to answer because the breadth of the used software spectrum is not known.

Calculation model

According to the assumptions of this cost model, the utilization of software distribution is calculated assuming that only a standard workstation is needed. On that basis, the additional evaluation, scripting, and installation of software packages on the server is not considered further in this cost model and also not applied to Clients. Instead, it is simply assumed that all necessary software is already installed on the server since the initial installation and only has to be distributed.

3.4.4.4.4 Energy costs

The operation of the server requires substantially more electricity than the operation of a workstation PC. Aside from the permanent availability (24x7,

365 days per year), the reason for that is the utilization of components with high electricity consumption such as two CPUs, much RAM, and quickly rotating hard drives. Added to that is the electricity consumption for cooling.

Calculation model

It is assumed that the operation of the server requires 215 Watts of power plus another 215 Watts for the cooling via the air conditioner. Given a permanent availability of 43 800 hours within the five year utilization period and a rate of 0.15 € per kWh, the resulting expense is 2 825.10 €.

Description	Costs per server	
Energy costs	2 825.10 €	-

3.4.4.5 Summary of the operating expenses

Description	Time expenditure	Costs
Server maintenance	7 800 min	4 241.97 €
Patch installation	2 600 min	1 413.99 €
Energy costs		2 825.10 €
Total	**10 400 min**	**8 481.06 €**

The total costs associated with the operation are 8 481.06 €.

3.4.4.6 Decommissioning

After the utilization period of five years, the server is decommissioned. Further use of the unit is possible but not considered in this study.

The first tasks of decommissioning encompass the deleting of the hard drives according to the IT security handbook, the updating of inventory lists and license documentation, and the disassembly from the 19" rack and storage until the final scrapping.

Another aspect of the decommissioning is the processing of the official decommissioning documentation which has to be processed by the IT management and the purchasing personnel.

Calculation model

The formatting of the six hard drives that will also be decommissioned takes several hours, but only a time expenditure of 30 minutes is considered for the cost model because the process can mainly take place without monitoring.

The server that is to be disposed of has to be stored. A time expenditure of ten minutes is assumed for this task.

Activity	Time expenditure per activity	Execution
Updating inventory list	10 min	Technician
Formatting hard drives	30 min	Technician
Decommissioning documentation	10 min	Technician
Decommissioning documentation	10 min	Purchasing manager
Disassembly from 19" rack	60 min	Technician
Storage	10 min	Technician

Description	Time expenditure per PC	Execution
Decommissioning	120 min	Technician
Decommissioning	10 min	Purchasing manager

Additionally, the disposal has to be considered, which is currently paid on a weight basis. A total cost of 90 € is assumed for this cost model.

Description	Costs per PC	
Disposal costs	90 €	-

3.4.4.7 Summary of the server-side costs

Description	Time expenditure	Costs
Purchase	9 830 min	8 319.50 €
Operation	10 400 min	8 481.06 €
Decommissioning	130 min	154.84 €
Total	**20 360 min**	**16 955.40 €**

In total, the costs for the software distribution system are 16 955,40 € for its life cycle.

Description	Time expenditure	Costs
Technician	20 315 min	11 042.71 €
Supervisor	10 min	5.02 €
Purchasing manager	35 min	17.57 €
Equipment costs		2 975.00 €
Energy costs		2 825.10 €
Disposal costs		90.00 €
Total	**20 360 min**	**16 955.40 €**

A large portion of the costs is associated with the time expenditure of the technician employee group because they establish the necessary infrastructure. It should also be noted that the user group is not directly involved here because the workstations are only indirectly affected by the server costs, and the direct costs in the form of work losses caused by restart for example are considered in the cost evaluation of the Clients.

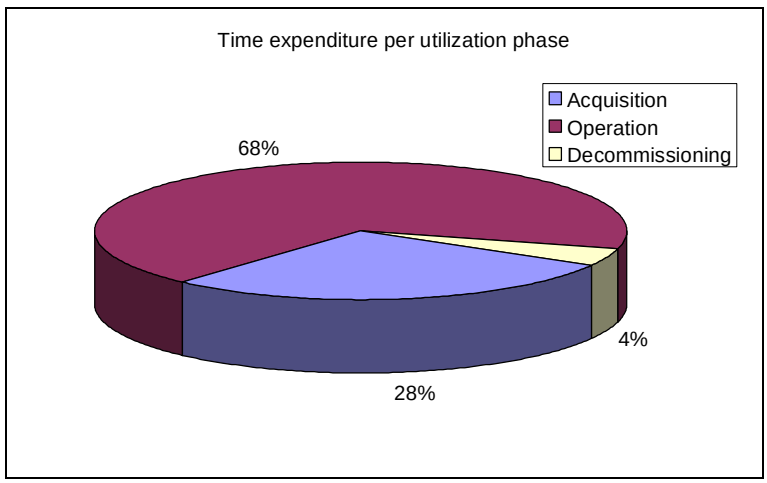
In order to get an overview of the costs per workstation, the following section shows the server-side costs allocated to the number of clients.

3.4.5 Cumulative cost assessment

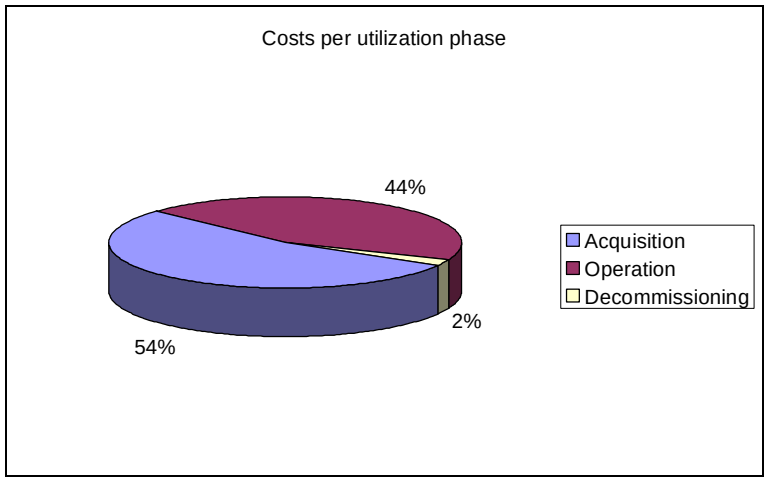
The costs for the management server explained above are now distributed to the number of clients so that the following total costs result per workstation assuming that 175 workstations have to be supported.

Description	Time expenditure	Costs
Technician	552 min	294.78 €
User	943 min	662.40 €
Supervisor	40 min	38.52 €
Purchasing manager	80 min	40.26 €
Equipment costs		827.00 €
Upgrade / replacement purchases		150.00 €
Energy costs		309.99 €
Disposal costs		25.51 €
Total	**1 615 min**	**2 348.46 €**

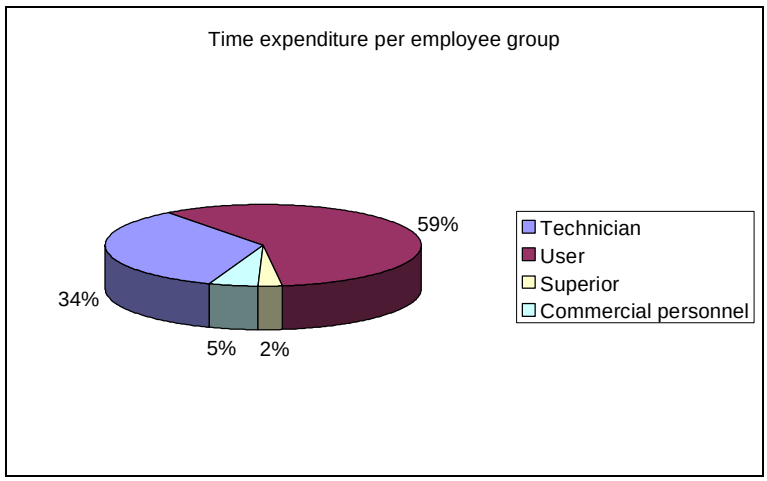
The time expenditure in the operating phase amounts to 68 %...



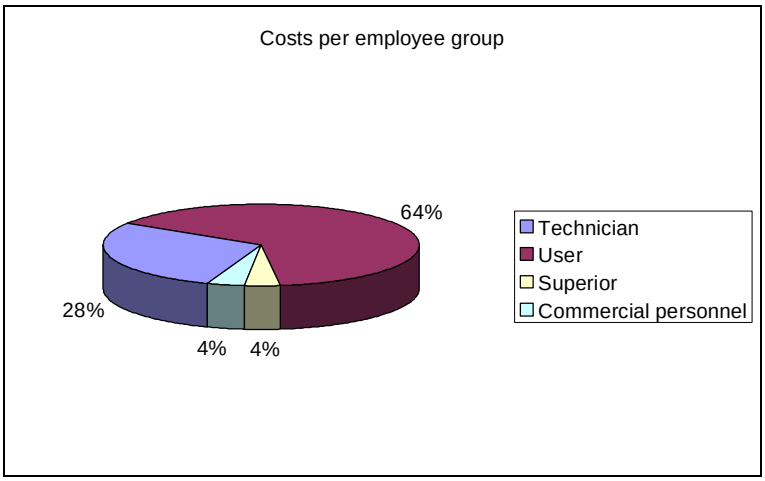
…whereas more than half of the costs accrue in the operating phase.



Classified according to employee groups, it becomes evident that the time expenditure for the user is very high at 59 % due to the unburdening of the technicians from manual intervention by automatic software deployment.



Based on the different personnel cost categories for various employee groups, the cost-related portion of the user is even as high as 64 %.



This is mainly due to the waiting periods and the above explained attempts at self help. This makes the cost savings concept of further relieving the user from PC-typical support expenditures all the more attractive. Whether and how this is possible through the utilization of servers and Thin Clients is the content of the next chapter.

4 Cost model Thin Client

4.1 Preface

This chapter answers the question of whether and under which conditions the use of Server Based Computing can be used to achieve savings compared to workstation PCs. In this context, the determination of TCO is not the focus but rather the evaluation of the costs that are associated with the utilized Client technology and that would change with the use of one technology to the other. Therefore, a separate cost model is developed for Server Based Computing in this chapter. The cost model is created under the assumption of a typical institute and is kept general enough that it can be adapted to specific, concrete conditions.

Another question that arises in connection with Server Based Computing is whether Thin Client technology can be utilized or whether the existing workstation PCs should be kept and equipped with the necessary software such as ICA® protocol. As opposed to using normal workstation PCs, the accruing costs for Server Based Computing have to be differentiated between server-side and client-side costs.

This chapter focuses only on costs that can be allocated specifically to Server Based Computing for the local operation of workstations at the user and the associated backend systems. That means that costs for the infrastructure, LAN, firewall, email, or wiring are not considered, this also includes periphery equipment etc.

Furthermore, the cost model is restricted to the use of application software based on Windows® which means that Microsoft® Terminal Server and possibly Citrix® will be used on the server-side exclusively. X11-based systems or other terminal protocols are not considered.

The assumptions and the evaluated costs coincide with the assumptions and evaluation items of the chapter about the specific costs of a PC workstation. This ensures a broad comparison of the individual expenses.

4.2 Utilization scenarios

In total, there are three different scenarios in which Server Based Computing is applied.

The first scenario is under the assumption that all used software is to be installed on the terminal server and that all users only utilize Thin Clients. This makes most sense when a comparably large group of employees uses a standardized, uniform workstation that is equipped with few software products, e.g. Office only.

The second scenario also entails that only a standard workstation is provided on the terminal servers. Every user that requires additional software has a PC on which the software is installed locally. The programs that are provided through the terminal server as a standard workstation are used via Citrix® Client. In this case, the number of necessary software installations on the terminal server is relatively low and, therefore, the costs for that are also especially low. One disadvantage is clearly that the number of workstations that do not need a PC and can use a Thin Client instead is definitely smaller than in the other scenarios.

A third scenario entails that every user has a workstation PC. Frequently used programs are installed locally. Seldomly used but expensive programs such a hazardous material data banks are provided on the terminal server. This approach exhibits advantages with the provision of applications at centralized locations but does not create savings compared to the conventional operation without the special software packages.

In the operational reality, these three scenarios will rarely be found in pure form. Especially, scenario 1 is idealistic but only realizable for all employees under certain circumstances.

Therefore, this cost model evaluates a variation of scenario 1. It incorporates the additional assumption that all software required by the users is installed and licensed on the terminal server. Thus, only handling costs for the acquisition are considered but not installation costs for this Client software. As part of the server costs, the costs that are associated with the installation and licensing of the server are allocated proportionally to the Client.

4.3 Individual cost model

4.3.1 Assumptions

In order to make a cost statement based on measured or estimated times, the corresponding times are assigned to the following person groups and each person group has a certain assumption regarding personnel costs per year.

Person group	Personnel costs/year
Technician	65,000 €
User	84,000 €
Supervisor	115,000 €
Purchasing manager	60,000 €

It is furthermore assumed that the average work time is 166 hours per month.

4.3.2 Objective of the evaluation

The following expenditures are investigated:

<u>On the Client side</u>

Acquisition costs:
- Configuration
- Order processing
- Initial installation
- Rollout to the user
- Software licenses
- Purchasing price of the hardware

Operating costs:
- Support
- Patch management
- Software installation
- Hardware installation
- Relocation costs
- Reinstallation
- Self help by the enduser
- Energy costs

Decommissioning
- Software uninstallation
- Disassembly and scrapping

On the server side

Acquisition costs
- Configuration
- Order processing
- Initial installation
- Software licenses
- Purchasing price of the hardware

Operating costs
- Support
- Patch management
- Software installation
- Maintenance, backup
- Energy costs

Decommissioning
- Software uninstallation
- Disassembly and scrapping

4.3.3 Assumptions of the cost model

The following assumptions are made for the cost model:

- Costs for infrastructure such as LAN wiring, switches, routers, and central network services are not considered.
- Overhead costs such as rent, insurance, security services, etc. are not considered.
- The following events will be considered in the life cycle of the Client:
    - Replacement purchase
    - Additional software purchase of which 2 are outside of the standard product portfolio
    - Active patch management
    - Proper decommissioning
- A Thin Client is used for five years.
- All values are averages.
- The costs for the acquisition of periphery equipment such as printers or monitors are not considered because they will not have a significant influence on the cost when switching to Thin Clients and Server Based Computing.
- Windows Server™ 2003 R2 Enterprise Edition and Citrix Presentation Server™ 4.0 also in the Enterprise Edition are used.

4.3.4 Utilization of Thin Clients

Thin Client implementation uses units at the workstation of the user that have no or comparatively low processing capacity. Resources such as CPU performance or main memory are very limited and the units have an operating system with limited possibilities. In the simplest form, Thin Clients are merely able to receive and display graphic information that is generated on the server and to send keyboard entries and mouse movements to the server. Higher-end Thin Client models also have additional features such as a built-in web browser, Java™ support, etc. This puts the Thin Clients much closer to Fat Clients, i.e. workstation PCs with local processing capacity. This also counts for the necessary support requirements for service packs, updates, and patches.

The Thin Clients assessed in this cost model belong to the former group without local processing capacity. In addition to diverse communication protocols, terminal emulation, and remote management functionality, it is assumed that the Thin Clients will only support the two application protocols ICA® from Citrix and RDP from Microsoft. All other features will not be considered.

Low failure probability

Thin Clients usually do not contain moving parts such as drives and fans, especially hard drives. This lowers the risk of failure according to the motto "If it is not equipped, it cannot break". In addition, the consequences of a failure are much lower compared to a PC because, where there is no local drive, nothing can be installed locally. All programs are provided from the server and, when a Thin Client fails, it can be replaced by another one. This eliminates the "Personal Computer" but rather just a computer that is arbitrarily exchangeable and low maintenance.

The utilization of Thin Clients is always sensible at standardized workstations with a manageable number of required software products. If the necessary software can be provided via the terminal server, the utilization of Thin Clients should be sought.

4.3.5 Implementation of workstation PCs

The implementation of classic workstation PCs in connection with Server Based Computing can have different causes and consequences on the expected costs.

4.3.5.1 Active PC

In this context, the term "active PC" exemplifies that the PC is used as such. This means that the PC still has an operating system and a user interface

through which the user can still utilize individual programs. The active PC has to be differentiated from the passive PC.

A possible utilization scenario for Server Based Computing assumes that a conventional, active PC is necessary in order to use specialty software. The software in this case is such that it cannot be run on a terminal server due to lacking compatibility or high resource demands as for CAD systems for example. The user utilizes this software locally and the remaining standard software such as Office will be made available via the terminal server.

Another utilization scenario for Server Based Computing encompasses that special, seldomly used software such as literature databanks are centrally installed on a terminal server. Users access the literature databank via their workstation PC using terminal software. This scenario is appropriate when expensive software is seldomly used by different people at various locations. In this manner, installation expenditure and, under certain circumstances, licensing costs can be saved.

Naturally, a mixture of these utilization scenarios is possible. For example, standard applications and seldomly used specialty software can be used simultaneously from somebody who is sitting in front of a CAD-workstation.

One advantage of the implementation of workstation PCs in combination with Server Based Computing is that the flexibility can be greater in some cases. In addition, a usually obsolete PC can be beneficially used which also eliminates the investment for the Thin Client. The mentioned advantages are countered by certain disadvantages. Many benefits of Thin Client technology can not be taken advantage of. The PCs still need operating systems that have to be installed, supported with service packs, and potentially equipped with more powerful software. In the case of a defect, not only does the question of a reinstallation present itself but also that of data loss.

4.3.5.2 Passive PC

In this context, a "passive PC" is a retrofitted PC with the local drives removed. Additionally, the CPU, RAM, and graphic card perform exactly as a Thin Client as a result of installed hardware and/or software. For example, there are suitable products from Thin Client manufacturers, so-called Thin Client cards, which can be installed in the PC as a plug-in card and download the necessary software from a CF card.

PCs retrofitted in that manner neither have their own operating system nor a user interface that can be configured or the possibility to utilize own programs.

The purchasing costs are below those of a real Thin Client but much higher than a pure software solution such as ICA® Client.

4.3.6 Client-side costs

4.3.6.1 Acquisition costs

4.3.6.1.1 Configuration

Hardware

Usually, one or two standard models with exact specifications will be defined in the product portfolio for the acquisition of Thin Clients. The specifications are not put together individually based on the requirements of individual workstations but are rather centrally determined for reasons of a unified administration, acquisition, and warranty processing.

In the case of a definite purchase, one unit will be chosen from the product portfolio and ordered. A traditional configuration process, which involves getting a quote from dealers that is individually tailored to the existing requirements, is not necessary anymore.

Software

For the configuration of the software, it is merely necessary to test whether the additional load can be covered by the existing servers. If this is not the case, additional servers have to be acquired.

Calculation model

The time expenditure for the hardware configuration amounts to ten minutes and is only necessary once. The time requirement for the software acquisition is assumed to be five minutes each.

Activity	Time expenditure per activity	Execution
Hardware	10 min	Technician
Software	5 min	Technician

In total, six software acquisitions will be performed.

Description	Time expenditure per Thin Client	Execution
Configuration	40 min	Technician

4.3.6.1.2 Order processing

The processing of the order necessitates the approval from a superior or a cost center officer. Following the approval, a simplified quote is obtained and the documentation is transferred to the purchasing department. The purchasing department then hands out the respective contract. In total, this process involves at least three persons plus four persons for the transferring of the quote documentation to the headquarters in Munich.

Calculation model

In total, it is assumed that every activity requires 10-15 minutes. The time expenditure is independent of whether it is for a Thin Client, a Thin Client card, retrofitting a PC, or software.

When old PCs are reused as terminal server client, the ordering process is not necessary.

Activity	Time expenditure per activity	Execution
Authorization	10 min	Supervisor
Quote request	15 min	Technician
Order processing	15 min	Purchasing manager

Based on the assumption that only two acquisition processes (only software) will be necessary in addition to the initial acquisition (hardware), the following list results:

Description	Time expenditure per Thin Client	Execution
Order processing	30 min	Supervisor
Order processing	45 min	Technician
Order processing	45 min	Purchasing manager

4.3.6.1.3 Initial installation

Typical tasks that are associated with the initial installation include the reception of the delivery, the inspection of the packing list, and the updating of the activity documentation. After a functionality test, the basic configuration of the Thin Client has to be adapted to the institute guidelines. This includes among other things the determination of the MAC-address, the arrangement of the IP configuration, and the registration of the unit at a remote manager.

Finally, the inventory lists and databases have to be updated with serial numbers, equipment descriptions and characteristics, and assigned licenses.

This updating process is similarly necessary for the central ERP system as it is for the IT management.

Calculation model

It is assumed that the reception of the delivery and the upkeep of inventory lists and licenses take 15 minutes each.

Values from practice have shown that the time expenditure for the individual activities is around 10 to 15 minutes. A differentiation between Thin Client and Thin Client card is not necessary.

Activity	Time expenditure per activity	Execution
Delivery reception	15 min	Technician
Basic configuration	15 min	Technician
Updating inventories and licenses	15 min	Technician
Updating inventories and licenses	10 min	Purchasing manager

Description	Time expenditure per Thin Client	Execution
Initial installation	45 min	Technician
Initial installation	10 min	Purchasing manager

4.3.6.1.4 Rollout to the user

The Thin Client has to be put into operation at the workstation of the enduser. Typical tasks to do that include the appointment coordination, transportation to the workstation, the disassembly of the old unit, the assembly and hookup of the new unit, and the transfer to the enduser. Additional tasks vary depending on whether Thin Clients were used before.

If the previous unit was a Thin Client, both units can be exchanged without problems without incurring any additional work.

If the old unit is a PC however, the user has to secure all locally saved data centrally on a server. Despite central memory management with centrally stored profiles and the requirement not to save data on local data carriers, practice shows time and time again that data is still locally saved even just as a "personal security concept" by manually backing up the data to a central fileserver every evening. Even if measures in the form of group guidelines or third party tools exist to prevent this form of local data saving, practice has shown that they are often not feasible to implement company-wide. If the old workstation was equipped with a PC, the user will have to get acquainted with the new unit and potentially need brief training by the technician.

Calculation model for Thin Clients

Assuming that the workstation of the enduser as well as the workstation of IT management is in the same location, a travel time of five minutes is assumed. Furthermore, the user is present during the assembly of the new unit. The disassembly of the old unit and the hookup of the new system require a time expenditure of an additional 20 minutes. The transfer of the unit itself to the user takes ten minutes as does transporting the old unit away. The user is assumed to take about 20 minutes for making himself familiar with the unit and the terminal server.

Scenario A assumes that the old unit is a PC.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Work loss during the securing of personal data	20 min	User
Transport to the workstation	5 min	Technician
Disassembly of old unit	10 min	Technician
Work loss due to disassembly of old unit	10 min	User
Assembly of new unit	10 min	Technician
Work loss due to assembly of new unit	10 min	User
Transfer	10 min	Technician
Transfer	10 min	User
Transport of old unit	5 min	Technician
Familiarization with new unit	20 min	User

Description	Time expenditure per Thin Client	Execution
Rollout to the user	45 min	Technician
Rollout to the user	75 min	User

Scenario B shows the time expenditures when the unit to be replaced is a Thin Client. This means that no time expenditure is necessary for data securing or the familiarization with the unit.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Transport to the workstation	5 min	Technician
Disassembly of old unit	10 min	Technician
Work loss due to disassembly of old unit	10 min	User
Assembly of new unit	10 min	Technician
Work loss due to assembly of new unit	10 min	User
Transfer	5 min	Technician
Transfer	5 min	User
Transport of old unit	5 min	Technician

Description	Time expenditure per Thin Client	Execution
Rollout to the user	40 min	Technician
Rollout to the user	30 min	User

Which scenario will be implemented more often will be different from institute to institute and will transform from scenario A to scenario B over the long-term.

In this cost model, scenario A is used because it is more likely to reflect the current situation at many institutes with a pending decision about Server Based Computing.

Calculation model for Thin Client cards

The prerequisites for the utilization of Thin Client cards are the presence of old PCs that can be retrofitted to become a passive PC.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Work loss during the securing of personal data	20 min	User
Travel to the workstation	5 min	Technician
Retrofitting the old unit	20 min	Technician
Work loss due to retrofitting the old unit	20 min	User
Transfer	10 min	Technician
Transfer	10 min	User
Travel back	5 min	Technician
Familiarization with the new unit	15 min	User

Description	Time expenditure per Thin Client	Execution
Rollout to the user	45 min	Technician
Rollout to the user	70 min	User

4.3.6.1.5 Software licenses

A Microsoft Server Client Access License (CAL) and a Microsoft Terminal Server Client Access License (TS-CAL) are required. Both have to be purchased per named device or named user.

Only the licensing costs for the utilization of the Citrix Presentation Server™ and the ICA® protocol will be paid on a concurrent-use basis. Concurrent-use means that only so many units or users can use the terminal server at the same time as licenses are held. The license is only occupied while it is being used. Once a unit is turned on, it occupies a license. It returns to the pool and is available for another user when the unit is switched off. Assuming that every user has exactly one unit and all use the terminal server at the same time, as many licenses as units have to be acquired. This assumption is made in this cost model.

However, other approaches are possible. For example, a certain portion of the employees are permanently on business travel, on vacation, or sick. The number of the employees or the portion of the total number of users is known due to statistical evaluation and also relatively constant. Thus, it would be possible to acquire a smaller number of licenses than units without breaching the license terms.

Additional license costs, especially for the acquisition of application software are accrued, but are not considered in this model as with the PC cost model (it is assumed that they will not change due to the Client technology).

Calculation model

It is convervatively assumed that a Citrix license is required for every device.

Description	Costs per client
Microsoft Windows Server 2003 Device CAL	20.00 €
Microsoft Windows Server 2003 Terminal Server Device CAL	53.00 €
Citrix Presentation Server 4.5 Enterprise User Connection	240.00 €
Total	**313.00 €**

4.3.6.1.6 Purchase price hardware

Thin Clients are available at an average price of approx. 300 €. Other hardware costs usually do not accrue because the Thin Clients do not need to be upgraded or require replacement parts.

Description	Costs per Thin Client
Purchase price	300 €

If a Thin Client card is acquired instead, the current price for that is about 120 €.

Description	Costs per Thin Client card
Purchase price	120 €

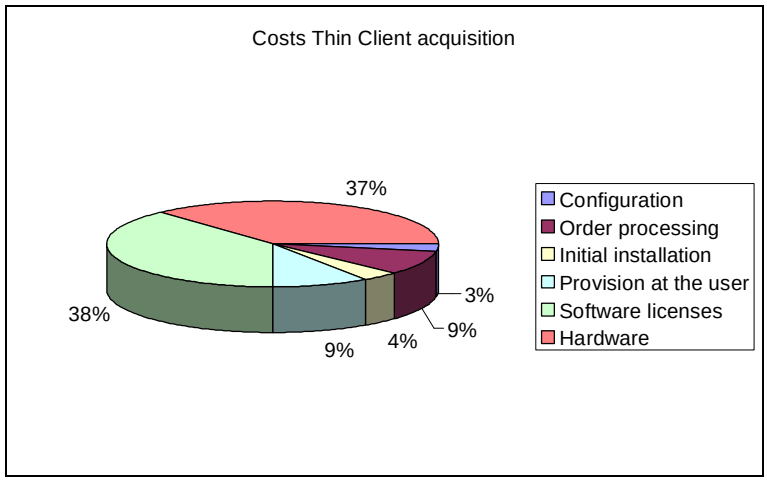
4.3.6.1.7 Evaluation of the Client acquisition costs

The acquisition costs are dependent on the initial situation among others. Aside from the concrete unit costs, determining factors are also the type of the unit to be replaced (PC, Thin Client) and the new unit to be acquired (Thin Client, Thin Client card).

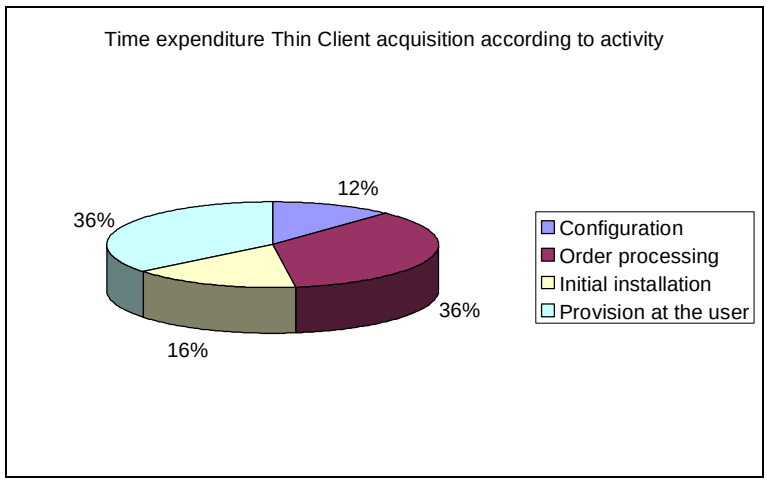
Description	Time expenditure	Costs
Configuration	40 min	21.75 €
Order processing	120 min	75.93 €
Initial installation	55 min	29.49 €
Rollout to the user	120 min	77.18 €
Software licenses		313.00 €
Hardware		300.00 €
Total	**335 min**	**817.36 €**

The table shows the most expensive case: A workstation PC is replaced by a Thin Client. This case will be the most likely one for the introduction of Server Based Computing.

If defective or outdated Thin Clients are to be replaced at a later time, the acquisition costs decrease by about 42 % to 470 €. The reasons for that are the already existing licenses as well as there is no need to archive local data.



75 % of the acquisition costs are associated with hardware and software licenses.

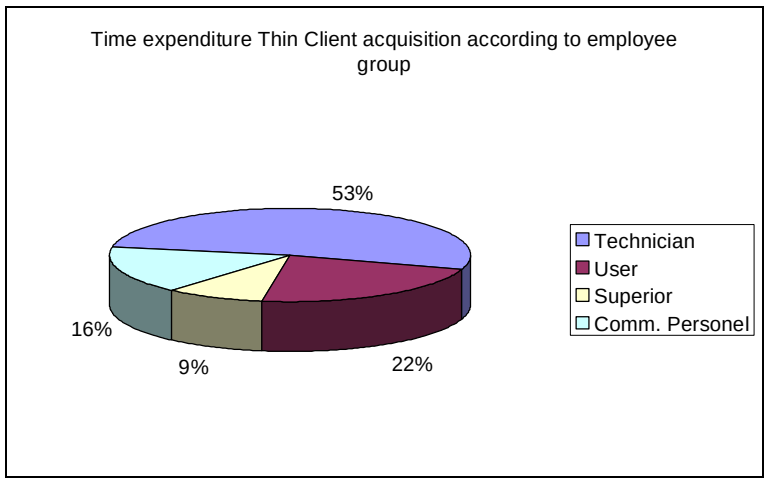


The time requirement for the installation is a mere 16%. In contrast, the order processing and the Rollout to the user are much more time intensive. This time requirement encompasses the transport and start-up of the new unit on site. Therefore, this area also causes work loss for the user who cannot work during these activities, has to move personal data to and from the PC to the server earlier[4], and has to make himself familiar with the new unit.

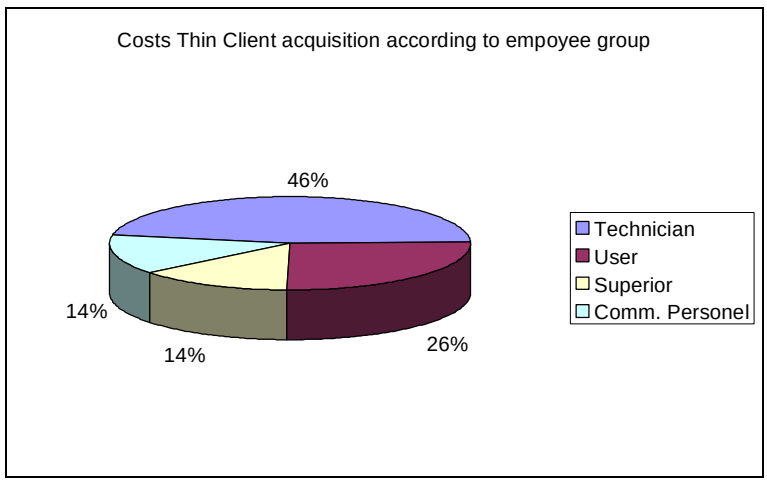
[4] Despite the directive not to save data locally, many users do it regardless so that additional expenditures are accrued when switching from a workstation PC to a Thin Client.

As the following table shows, the employees of the technician group have the highest time expenditure associated with the acquisition.

Employee group	Time expenditure	Costs
Technician	175 min	95.17 €
User	75 min	52.71 €
Supervisor	30 min	28.87 €
Purchasing manager	55 min	27.61 €
Total	**335 min**	**204.36 €**



The percentage portion of the time expenditure of the IT management during the acquisition totals 53 %.



Based on different personnel costs, the cost portion of the technician employee group decreases to 46 %.

4.3.6.2 Operating costs

4.3.6.2.1 Support

The expenditure for support associated with the maintenance and reestablishment of full functionality of the workstation accumulates constantly. If a Thin Client fails due to a defect, it is usually replaced with a new unit. However, the failure rate of Thin Clients is significantly lower than that of a normal PC because it does not contain moving parts.

The support related time expenditure is generally substantial. This is shown by the results of a questionnaire. Whether this support expenditure can be assigned to a specific platform such as PC or Thin Client, or whether it is rather related to operating problems, incompatibility, or errors in the software that are independent of the utilized operating system, cannot be determined on the basis of the results.

In the context of the model, these costs only play a minor role because the utilization of Server Based Computing is only chosen if it can be clearly proven that the software runs on the terminal server as specified. If this is the case, the costs should be analogous to the PC cost model and are, therefore, also not considered in this model.

If a problem occurs anyways, another advantage of Server Based Computing arises due to the central administration. Support employees do not have to let the user painstakingly explain the problem and then have to go to the PC of the user anyway in order to assess the situation from there. Instead he can use remote administration tools to comfortably switch to the session of the user and follow the actions of the user if necessary.

A newly arising problem will be that the determination whether a specific support case is a problem of the Client or the server will not always be clear initially. This problem will be minimized as the technician's experience increases.

4.3.6.2.2 Installation of service packs and patches

Since nothing is locally installed for Thin Clients, the client-side installation of service packs is neither necessary nor possible. Therefore, the installation is performed at the terminal server.

However, if the units that are used for Server Based Computing are active PCs, the expenditures are analogous to those described in the PC cost model. The absolute amount of these expenditures is, therefore, again dependent on which programs are installed locally and which are used via the terminal server.

Calculation model

The costs per server will be proportionally allocated to the Clients for the calculation of the installation costs for service packs and patches.

4.3.6.2.3 Software installation

Software will be installed exclusively on the terminal server when Thin Clients are utilized. A local installation is neither necessary nor technically possible (see above).

If the program is already installed on the terminal server (this coincides with the assumption), the user is simply added to a previously defined group to allow him access to the program. In addition, the relevant license documents and inventory lists have to be managed.

Calculation model

Adding a user to a group only requires a very small time expenditure. The postprocessing encompasses the updating of licenses and the information of the user about the completed addition.

Activity	Time expenditure per activity	Execution
Release program	5 min	Technician
Postprocessing	5 min	Technician

In total, 6 software packages are used.

Description	Time expenditure per Thin Client	Execution
Software installation	60 min	Technician

4.3.6.2.4 Hardware installation

Not only are hardware installations on Thin Clients not intended, but they are usually not technically possible. When defects occur, Thin Clients are simply replaced by new units.

4.3.6.2.5 Relocation

If a user who uses a Thin Client or a passive PC has to relocate and a Thin Client is available at the new location, neither of the two Thin Clients have to be moved. The user simply uses the existing unit at his new workstation. This eliminates moving costs that would have to be considered in this cost model.

It is different if there is no Thin Client at the new location. In this case, the user usually takes his Thin Client with him. Possible alternatives such as a revolving change are not considered. If the user takes the Thin Client with him, the same costs accrue as they are described in the PC cost model.

Calculation model

It is assumed that for every second relocation of a user a Thin Client will have to be moved. This assumption reflects the fact that an institute will not use Thin Clients exclusively in the foreseeable future. It is assumed for the calculation that one move occurs in a five year period. This assumption is the same as in the PC cost model.

Activity	Time expenditure per activity	Execution
Appointment coordination	5 min	Technician
Appointment coordination	5 min	User
Travel to the workstation	5 min	Technician
Completing the relocation	60 min	Technician
Work loss during relocation	60 min	User
Return travel	5 min	Technician
Updating inventory	5 min	Technician

Activity	Time expenditure pre Thin Client	Execution
Relocation	80 min	Technician
Relocation	65 min	User

4.3.6.2.6 Reinstallation

A reinstallation such as with PCs based on a hardware failure, an erroneous software installation, or an operating system change is not necessary for Thin Clients.

4.3.6.2.7 Personal administration and self help

The personal configuration of the desktop and the personal work environment is subject to more guidelines than for a workstation PC. First of all, the user does not have a configurable desktop at his disposal. At times, only few programs or even just one program are released to the user. Then the possibility to individually configuration is eliminated completely.

Even if a desktop is available, the possibilities are further limited compared to the profiles on local PCs due to the usual preconfiguration of the terminal server. Thus, the user does not have the opportunity to access programs other than those released to him. Additionally, the possibility to change settings such as the screen savers or desktop backgrounds should be deactivated by the

administrators for reasons of conserving server resources. There is also no possibility for the user to install software himself.

One immeasurable effect is which relationship exists between the local configuration of the PC and desktop and the support requirements. Due to the unification resulting from the mentioned limitations, it can generally be assumed that the diversity of the occurring problems should be limited and, at the same time, the experience for their elimination should be increased. In the medium term, both leads to a reduction of support cases or an acceleration of their solution.

Calculation model

Due to the reduced possibilities, a significant decrease in the user's time expenditure for configuration and self help can be assumed. In this cost model, a time expenditure of two minutes per month is assumed which is to be seen as an average value. It is much more plausible that every tenth user spends 20 minutes per month with individual configuration and self help.

Activity	Time expenditure per activity	Execution
Self help	2 min	User

Activity	Time expenditure per Thin Client	Execution
Self help	120 min	User

4.3.6.2.8 Energy costs

Just like all other electronic equipment, Thin Clients consume electric energy during their operation. Based on the low number of components as well as the lower performance of the CPU, RAM, and graphic card, the electricity consumption is significantly lower than that of a modern workstation PC. This is discussed in detail in [UMSICHT 2008].

Calculation Model

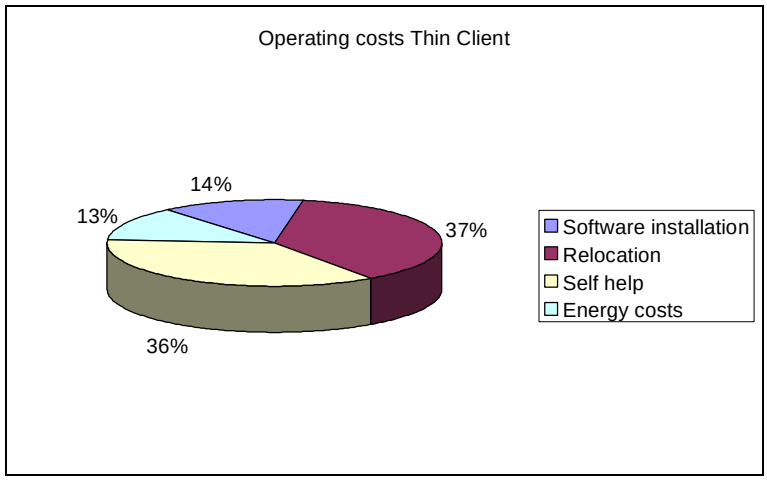
An average Thin Client – not a passive PC or a retrofitted PC – consumes about 17 Watts (without monitor) when running and approx. 1 Watt when switches off ("Soft-Off"). Assuming nine working hours per day (Thin Clients are rarely turned off during breaks) this makes up an average consumption of 7 W over 24 hours. Further assuming an electricity price of 0.15 €/kWh, the Thin Client causes energy costs 30.33 € over its five year utilization period.

Description	Costs per client
Energy costs 220 working days	27.72 €
Energy costs 145 days in standby	2.61 €
Total	**30.33 €**

4.3.6.2.9 Evaluation of the operating costs

The operating costs of a Thin Client are low compared to the operating costs of a workstation PC. All activities related to the support for hardware defects, software installations, hardware upgrading, or reinstallation are unnecessary.

If a workstation PC is used instead of a Thin Client regardless of whether as a standard workstation or specialty applications are used via the terminal server, the costs remain unchanged as described in the cost model PC.



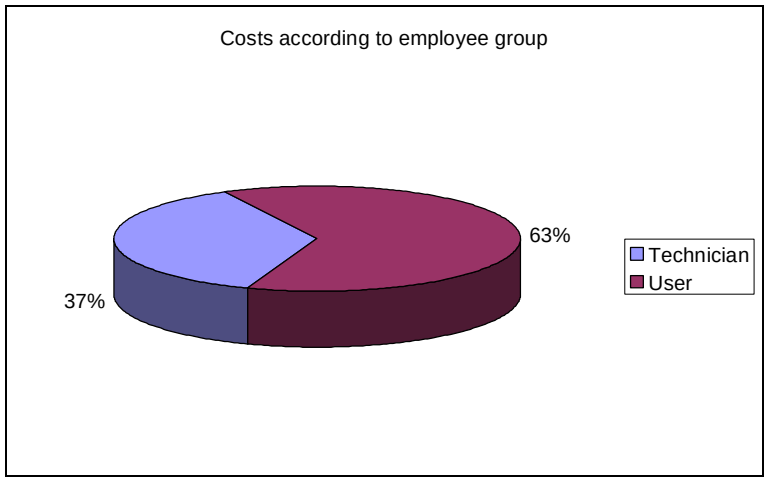
Despite limited possibilities, self-help according to the "Hey-Joe" support method[5] are still the largest expenditure. In absolute terms, the portion of the self-help costs decreases significantly and probably is close to zero for the majority of the users. Therefore, a time expenditure of two minutes per person and month is assumed for those who still attempt to connect hardware, install drivers or software, or to take the screw driver to the unit. This is 60% less than for the PC after all.

If there is already a Thin Client at the new location of the user, the relocation costs could fall away completely.

5 The expression „Hey Joe Support" was coined in the USA. A user who has a problem with his PC asks his colleague „Joe" for support first.

The software installation encompasses the activities of the administrator to release a program installed terminal server to the user and adding the user to a corresponding release group.

Activity	Time expenditure	Costs
Software installation	60 min	32.63 €
Relocation	145 min	89.19 €
Self help	120 min	84.34 €
Energy costs		30.33 €
Total	**325 min**	**236.49 €**



2/3 of the operating costs are associated with the user himself.

4.3.6.3 Decommissioning

At the end of the utilization period, the Thin Client will be disassembled at the workstation, taken out of service, and disposed of. Based on the five year utilization period assumed in this model, a reuse of the unit is not considered.

Several tasks are associated with the decommissioning. First, the inventory data for this unit has to be updated. Used licenses have to be managed in the corresponding lists if they have not been transferred to a new unit yet.

Another aspect of the decommissioning is the official decommissioning documentation which has to be processed by the IT department and the purchasing personnel.

Calculation model

The Thin Clients that are to be disposed of have to be stored. A ten minute time expenditure is calculated for this task.

Activity	Time expenditure per activity	Execution
Update inventory list	10 min	Technician
Decommissioning documentation	10 min	Technician
Decommissioning documentation	10 min	Purchasing manager
Storage	10 min	Technician

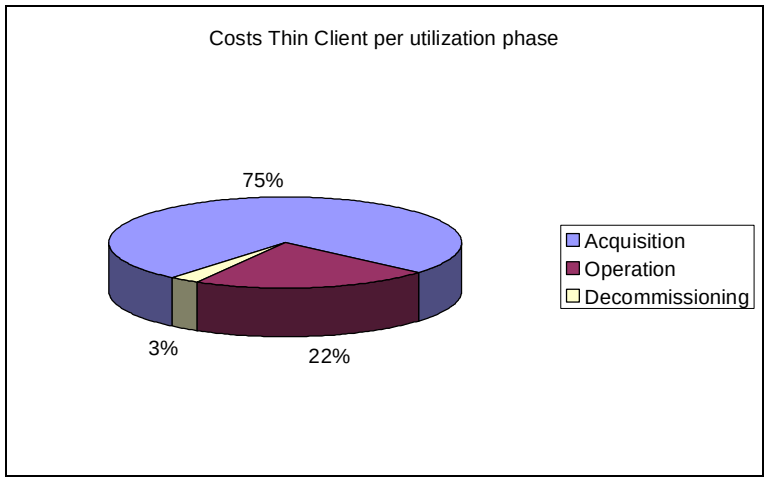
Description	Time expenditure per Thin Client	Execution
Decommissioning	30 min	Technician
Decommissioning	10 min	Purchasing manager

Added to that are the disposal costs for the electronic scrap which is currently paid according to weight. A cost of 10 € per Thin Client is assumed for this model.

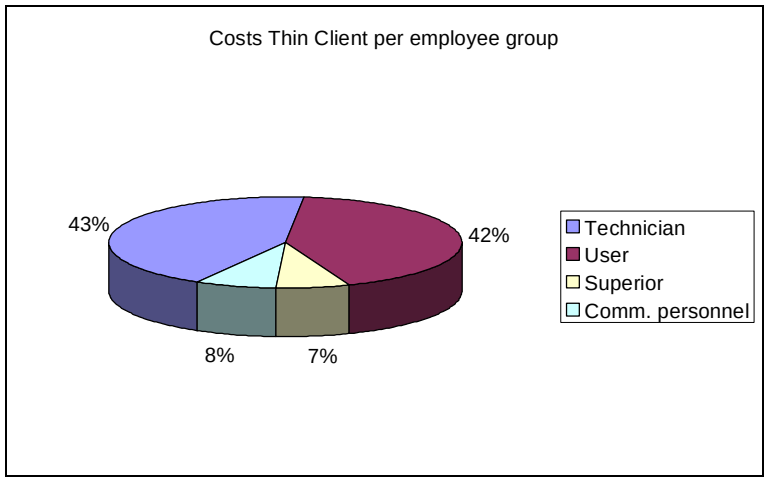
Description	Costs per Thin Client	
Disposal costs	10 €	-

4.3.7 Client evaluation

Utilization period	Time expenditure	Costs
Acquisition	335 min	817.36 €
Operation	325 min	236.49 €
Decommissioning	50 min	31.34 €
Total	**710 min**	**1 085.18 €**



75 % of the total costs are associated with the acquisition. Naturally, this value is mainly determined by the hardware costs and software licenses.



The costs are relatively evenly distributed between users and technicians.

4.3.8 Server-side costs

4.3.8.1 Acquisition

4.3.8.1.1 Server sizing

Generally server sizing involves answering the question of how much main storage, how much processing capacity, and which processors the server needs to be equipped with in order to handle a certain load successfully. Unfortunately, this brings up two additional questions. First, what is a certain load? Second, what is meant by successfully handle?

In addition to answering the apparent questions of how large the hardware has to be to handle a given load, the question of what load can be handled by a given, potentially already purchased server has to be answered.

For both approaches the following considerations apply.

The user of the terminal server has to be able to work fluidly. This means that an instant reaction follows mouse movements and key strokes as well as the undelayed scrolling in documents or the instant display of display excerpts has to be enabled. This is especially important because a bad response time behavior in these basic functions has a very negative influence on the user acceptance of terminal server technology in general.

In addition, the processing of calculations, the spelling check, or the updating of a spreadsheet should allow a fluid working and should, therefore, not lag behind the performance of a dedicated workstation PC.

If the user has bad experiences here even for a short time period, the user will reject the utilization of Thin Client technology and Server Based Computing and seek the possibility to work on a local workstation PC as practice has shown time and time again. Surprisingly, a user is more critical of Server Based Computing than his own, potentially equally underperforming workstation PC. However, there are positive examples from institutes in which the users turned down their workstation PCs due to the superior performance of the terminal server and preferred to work with a Thin Client.

Influencing factors on the computation load

The generated load depends on the user and the utilized software. First, there are different types of users that not only use different software for different tasks but also have individual behavior patterns. For example, while one user only opens the application he is currently using and closes it before using another, another user with the same tasks opens all applications in order to go back and forth between them at will. These different behavior patterns have different influences on the memory demands and processor load.

For reasons of simplification, some manufacturers categorize users into three groups such as light user, medium user, and heavy user, for example.

User type	Utilization	Description
Light User	Usually only uses one application. It is primarily a program for data acquisition or email.	Only has very small demands on the computing power.
Medium User	Uses two or three applications simultaneously. This includes Client/Server- applications with database access but also tools such as MS Office.	The demands on the computing power are higher than the Light User.
Heavy User	Always uses several applications simultaneously and processes large documents and works intensively with Outlook® and Excel® incl. diagram generation etc.	Highest computing power required and higher main memory requirements.

An additional factor for the generation of a load to be handled is the utilized software. Is it a word processing system that, according to computer standards, has to wait for the next key entry indefinitely, or is it a computing-intensive task such as a scientific simulation?

The question of whether the software is a 64-bit, 32-bit, 16-bit application or even a DOS-application plays another role. Generally, 64- and 32-bit applications should be preferred because 16-bit or DOS-applications sometimes require significant resources in the form of main memory and CPU time.

For reasons of simplification and since Fraunhofer UMSICHT does not currently have experience values from a longer productive operating phase of 64-bit servers, this cost model bases its calculations on **32-bit** applications.

RAM

The main memory plays an important role in the scalability and performance of a terminal server. Too little main memory forces the operating system to revert to the hard drive which results in a noticeable decrease in the response time behavior and, thus, the performance of the whole system.

In order to determine the definite memory requirements, it is not sufficient to measure these parameters on a single workstation PC and to interpolate to the number of users. Unfortunately, this approach leads to wrong, inflated values. When using the terminal server, a program is loaded into the memory only once which means that for the first user memory is used for the program code and local data while only memory for the local data is required when a second user starts the program. On the one hand, it would therefore be wrong to multiply the main memory space of a single PC with the number of users to determine the total memory required for the server. On the other hand, the data provided by the manufacture should be questioned as well. They give the memory requirements in very small values of a few MByte. These values do not seem to be realistic because the assumptions about the size of the processed documents, the used monitor resolution, the color depth, and other factors influencing the memory demands are not well defined in these recommendations.

Based on experience we recommend that at least **64 MByte** of memory should be provided on the terminal server for every user (Medium User). Therefore, this value is used for the server sizing.

Added to that are the memory requirements for basic services and the operating system itself. In this case, the given values from Microsoft should be viewed with skepticism. The suggested basis values of 128 MByte (minimum) and 256 MByte (recommended) for the terminal server are definitely too low even for Windows® 2003. We recommend providing **512 MByte** memory as basis for the operating system.

Memory	Number of users
512 MByte	0
1 024 MByte	8
1 536 MByte	16
2 048 MByte	24
2 560 MByte	32
3 072 MByte	40
3 584 MByte	48
4 096 MByte	56

The use of more than 4094 MByte memory is not recommended for various reasons at least on 32-bit servers. Since Windows® 2003 as the current 32-bit operating system can only directly address 4096 MByte of memory, the use of additional memory is generally possible (with the help PAE, Physical Address Extension) but not recommended due to inherent system restrictions in the area of kernel resources.

CPU

The correct determination of the required CPU for the operation of a terminal sever with a planned load in advance is actually impossible. Moreover, the actual load would have to be measured and then converted. In order to do that, a beginning basis has to be defined which establishes how much delay during the processing of normal mouse movements and key entries is acceptable, how much time can pass until a dialog box opens, etc. The whole process is very work-intensive, is only executable for a specific hardware configuration, and the tests for the generation of the load that serves as basis for the measurement has to be automated. In order to make this task easier for the customer or eliminate it completely, the manufacturers offer appropriate software tools. The assumptions that make up the basis are usually only conditionally transferable which then also holds true for the results. For this reason, we estimate that the necessary processor capacity is significantly higher than the recommendations of the manufacturers. For example, Microsoft gives a maximum user number of 200 Knowledge Workers (equivalent to the Medium User group) for a 2.4 GHz Xeon processor in a whitepaper [MS 2003] on this topic. This value does not coincide with experience from practice and should be handled similarly to the hardware recommendations for Windows® operating systems.

We currently recommends an Intel® Xeon DP 3.4 GHz processor as a basis processor. This processor is currently one of the most powerful processors for dual processor configurations and is a good starting basis to process a load of at least ten users.

Network

The network is responsible for the whole communication between terminal server and client. It "transports" the mouse movements and key entries as well as the display contents, the print data when local printers are used, or the data streams of locally mapped drives. Thus, the network has a significant influence over the performance perceived by the user. This performance is shaped by two characteristics: the data transfer rate and the latency. While the data transfer rate determines the maximum amount of data that can be transferred in a given time interval, latency describes the time that passes between the sending of a data package and the reception of the same data package. Based on very efficient compression, the requirements on the bandwidth for the ICA® protocol are not very high so that a simple ISDN connection might suffice as a connection to the Client. However, latency is important. It is determined by the processing speed of the network components among others. When the network is overloaded itself, the switches are working at the limit, or the backbone connections between the servers are working at full capacity, it leads to an increasing latency and, thus, directly to a performance experienced as slow.

It is not the focus of this cost model to develop recommendations and cost calculations for a high-performance network. More so, the responsible parties for the planning of the utilization of Server Based Computing should adequately consider the network factor and test whether the necessary prerequisites are fulfilled.

Server size

The recommended well-equipped unit with four GByte memory and Xeon DP CPUs has shown that a maximum of 35 users should work on one based on operating experience at Fraunhofer UMSICHT. Such a configuration has the potential to have a calculated number of users and still have certain reserves to serve more users on short notice or to provide a more computing-intensive application for a few users. Such a limited reserve capacity is important for emergency and maintenance planning which need to be considered.

Such a server has a build height of 1U and a relatively inexpensive purchase price. The next larger servers with four processors with eight, 16 GByte or more RAM are not only unproportionaly more expensive but also have features such as SCSI subsystems with RAID 5 or 1+0 functionality that are not needed for the terminal server application.

This server recommendation follows the idea of "many small ones rather than few large ones". The disadvantage is the higher maintenance requirements and higher licensing costs for the operating system Windows Server™ 2003. In

contrast to that is the large advantage that the entry costs and fixed-step costs (the costs that accrue for the acquisition of an additional server e.g. for the 36th user, the 73rd user, etc.) are lower.

Emergency and maintenance planning

The outage of a single workstation PC due to a defect or update installations, patches, etc. leads to the work loss of a single user and thus to the decrease in the productivity of that user. If a single or even several terminal servers are down, 35 or more, potentially even all, users are affected. The economic damage is correspondingly large. Suitable measures can be employed to counter that. The prerequisite for that are the creation of redundancies, the elimination of relevant single points of failure, as well as the utilization of high-quality components.

Redundancies can be created in several ways. A first redundancy is accomplished through the utilization of mirrored hard drives. For this important aspect, high-quality SCSI hard drives should be used on the servers exclusively. The hard drives should be mirrored via RAID 1. This not only has the advantage that the outage of one hard drive does not significantly influence the operation of the terminal server, but it also is an equally important advantage that a new system configuration can be secured by simply exchanging one of the two hard drives with another. The exchanged drive is put into a closet and represents a backup of the system configuration.

Therefore, we recommend the acquisition of three hard drives with a minimum capacity of 36 GByte as well as servers that have hard drives that can be accessed from the outside with hot-swap functionality.

In addition, at least one more server than actually needed has to be available and ready to operate in case of outages and for updates, software installations. This also secures the full operational readiness of the entire terminal server farm even during the outage of a server due to a defect or for maintenance work. This server has to be viewed as an additional, fully capable productive server. This means that the server does not only have to be equal in hardware equipment but also has to be on the same level as the other servers in terms of software. All the servers form a part of the server farm and the load is equally distributed between them via Load-Balancing for example.

Number servers	Reserve server	Users/ server	Total users	Capacity	Total user capacity	Required servers
1	1	35	35	200%	70	2
2	1	35	70	150%	105	3
3	1	35	105	133%	140	4
4	1	35	140	125%	175	5
5	1	35	175	120%	210	6
6	1	35	210	117%	245	7
7	1	35	245	114%	280	8
8	1	35	280	113%	315	9
9	1	35	315	111%	350	10

This model is only valid under the assumption that all servers host the same applications. If this is not the case and the terminal server farm is configured such that a group of a servers each hosts different applications, one reserve server is not enough and a reserve server per application group would be needed.

In addition, the purchase of a maintenance contract is highly recommended in order to get a replacement for the defective unit or have the repair work to fix the broken server completed as quickly as possible.

Recommendation

Generally, the topic of server sizing is highly complex, and experienced professionals should be consulted in addition to current, appropriate literature for concrete projects. The assumptions and simplifications made in this calculation model are also made in order to limit the complexity of this document. Therefore, this section should not be seen as a guideline for server sizing.

4.3.8.1.2 Configuration

In this context, the configuration is the process in which the requirements and necessary specifications are set for the server to be acquired. One task initially is the server sizing. Since the approximate recommendations for server sizing are generally known from the above mentioned recommendations, the time expenditure for the acquisition is relatively low.

Subsequently, offers have to be gathered from the market place. The boundary data or product specifications have to be given to several vendors and the incoming offers have to be compared and evaluated. The best offer will be transferred for authorization.

The quote gathering is moved into this phase deliberately compared to the acquisition of workstation PCs because this process is closely related to the server sizing process and might have to be repeated.

Calculation model

The time expenditure for the configuration is only necessary once. However, it is higher than that for the initial purchase of the workstation PC or even a Thin Client. A time expenditure of three hours is assumed.

Activity	Time expenditure per activity	Execution
Server sizing	15 min	Technician
Obtaining quotes	15 min	Technician
Evaluate quotes	15 min	Technician

Description	Time expenditure per server	Execution
Configuration	45 min	Technician

4.3.8.1.3 Order processing

The acquisition of a server first requires the authorization from a superior or a cost center officer who is usually the head of the IT department. The authorization is followed by the transfer of the documentation to the purchasing department and the contracting of the vendor.

Calculation model

Description	Time expenditure per server	Execution
Authorization	30 min	Supervisor
Contract processing	15 min	Purchasing manager

4.3.8.1.4 Initial installation

The initial installation encompasses the reception of the delivery, the inspection of the packing list, the subsequent assembly in a 19" rack, as well as the installation of the operating system including the necessary drivers, all current service packs and patches, and the configuration as a terminal server. This also includes the installation of the Citrix Presentation Server™.

In the next step, the application programs to be hosted are installed on the terminal server. The installation is finished by installing all relevant service packs, patches, and hotfixes.

The packing list and other purchasing documentation are passed on to the appropriate department, and the data in the inventory lists and ERP-system are updated.

Calculation model

The assembly and the basic installation of the operating system requires about six hours of time. The subsequent installation of the software applications to be hosted is more time-intensive because not only do the corresponding operation modi (installation mode vs. application mode) have to be considered, but the individual installation processes such as transformation scripts have to be utilized also. In contrast to workstation PCs, the additional time expenditure based on these measures increases the total duration to 16 hours.

It is assumed that the basic knowledge of how certain software is installed on the terminal server is known through previous evaluation and/or the appropriate documentation.

Activity	Time expenditure per activity	Execution
Delivery reception	15 min	Technician
Basic installation including assembly, operating system, Citrix Presentation Server™	360 min	Technician
Install applications	960 min	Technician
Update inventory and licenses	15 min	Technician
Update inventory and licenses	10 min	Purchasing manager

Description	Time expenditure per server	Execution
Initial installation	1 350 min	Technician
Initial installation	10 min	Purchasing manager

4.3.8.1.5 Software licenses

For the operation of the terminal server, Citrix Presentation Server™ 4.5 is usually necessary in addition to the operating system Windows Server™ 2003 R2 Enterprise Edition.

Windows Server™ 2003 R2 should therefore be utilized in the Enterprise Edition because the optimized storage behavior leads to noticeable speed advantages compared to Windows Server™ 2003 Standard Edition.

The Citrix Presentation Server™ is also utilized in its Enterprise Edition. The reason for that is that compared to the normal edition this version has Load-Balancing ability and enables a flexible allocation of users to lower load servers. This not only makes administration easier but is also a prerequisite for

uninterrupted availability (with certain restrictions) of the whole terminal farm in case of a temporary deactivation of a single server during maintenance work. Citrix Presentation Server™ does not have to be licensed per machine. Instead, the software is provided as a freely capable media kit that can be installed on any number of servers. Rather then licensing the server, the Clients are licensed through a licensing model on Concurrent User Basis.

In addition, the use of an online defragmentation program is recommended. The use of such a program reduces or completely eliminates the fragmentation of the file system which inevitably occurs from frequent copying of user profiles. Without regular defragmentation, individual files are located on different areas of the hard drive so that increased movements of the read/write head are necessary.

Calculation model

Software	**Costs per server**
Windows Server™ 2003 R2 Ent. Edition	1 540.00 €
Defragmentation software	350.00 €
Total	**1 890.00 €**

4.3.8.1.6Purchase price

The purchase price of the server includes the costs for the hardware itself as well as a five year maintenance contract with a reaction time of the next work day.

Additional costs for uninterrupted electricity supply are not considered as part of this cost model.

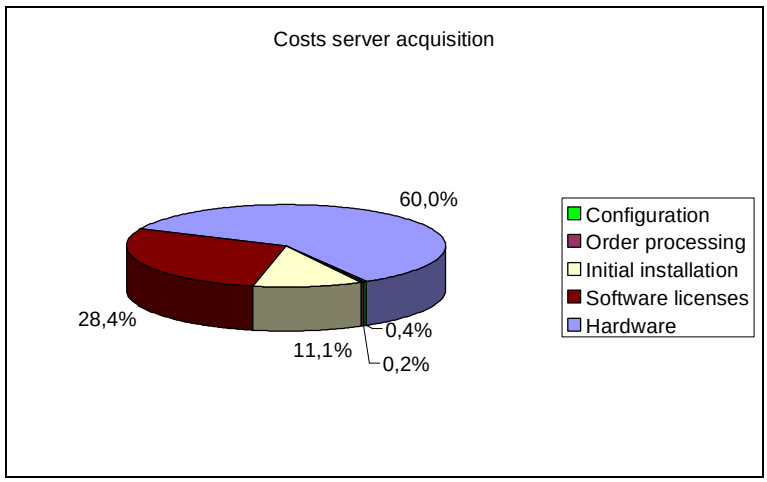
Calculation model

The purchasing price for a server system is based on the productive terminal server environment as it is utilized by Fraunhofer UMSICHT. A current HP ProLiant DL360 G4p with 2x 3.4 GHz Intel Xeon CPU is acquired. The server is equipped with 3x SCSI 36.4 GByte hard drives of which one hard drive with current system configuration is used as a backup drive. We assume a purchasing price of **4 000 €**.

4.3.8.2 Evaluation acquisition costs

Description	Time expenditure	Costs
Configuration	45 min	24.47 €
Order processing	25 min	12.55 €
Initial installation	1 360 min	739.21 €
Software licenses		1 890.00 €
Hardware		4 000.00 €
Total	**1 430 min**	**6 666.23 €**

The total acquisition costs for a server are 5x higher than those for a workstation PC and almost 10x higher than those for a Thin Client.



Approximately 88 % of the acquisition costs are associated with hardware and licenses.

4.3.8.3 Operation

4.3.8.3.1 Support

The support for a server encompasses security, monitoring, and reestablishment of full functionality. The concrete tasks here include the monitoring of event logs, the measurement and evaluation of performance and operating parameters such as CPU load, main memory utilization, free memory space, etc. Additionally, hardware parameters such as temperature and status messages of individual components have to be monitored and controlled regularly. These tasks can be summarized under the term server monitoring and can be performed very efficiently and in a time saving manner using tools such as LANrunner®.

The administrator only has to intervene when the value diverge from the normal, expected values as would occur during hardware failure, error messages in the event log, or analog, application specific files, insufficient memory space, etc.. For hardware failures, a corresponding maintenance contract is presumed, the contract partners are informed, and the correct completion of the services is monitored.

The completion of backups is usually not necessary if the terminal server is not also simultaneously used as file and application server as implied in this cost model and if a hard drive is exchanged, replicated, and stored.

Calculation model

The time expenditure for the mentioned tasks is largely dependent on the support from the utilized management tools. It is assumed for this cost model that a high-performance solution is used, and the resulting administrative and monitoring efforts per server would take an average of 30 minutes per week. In 52 weeks or a five year utilization period, this leads to a total support requirement of 7,800 minutes.

Activity	Time expenditure per week	Execution
Server support	30 min	Technician

Activity	Time expenditure per server	Execution
Server support	7 800 min	Technician

4.3.8.3.2 Installation of service packs and patches

The installation of service packs and patches is accomplished centrally on the terminal server. This means that all users can immediately and uniformly use the updated version of the software. A local installation is neither necessary nor possible for Thin Clients.

It is certainly necessary to install all of the patches and updates provided by the manufacturer. Naturally, this is especially true for all security related updates. The disadvantage is that it is not recommended to wait for planned downtimes to install the patches or other countermeasures especially during imminent threats of viruses and worms. In such exceptional cases, an appropriate installation has to be performed immediately. This installation is usually associated with a restart of the server which inevitably leads to the termination of the user sessions. The frequency of this measure depends on the number and severity of each threat. Therefore, the absolute number of the necessary patches is not plannable or predictable.

Additional caution should be taken with the installation of service packs and other large updates. Since all users are equally affected, it has to be ensured that inherent changes in the functionality from new versions or service packs do not cause conflicts for existing documents, macros, programs, or software of other manufacturers. Although these requirements also exist for workstation PCs, it is especially problematic here since all are affected without exceptions.

Calculation model

When installing patches at a workstation, the technician cannot leave the PC on which he is logged on as administrator unsupervised. He sometimes has to continuously supervise the progress of the installation. This is different for the maintenance of a server. In this case, the administrator can already prepare or begin the next installation after initiating the previous one which is completed automatically. Therefore, duration and time expenditure need to be differentiated in this calculation model.

Furthermore, it is assumed that there will be one planned downtime per month which can be used for the installation of patches without incurring work losses from the user.

Activity	Time expenditure per activity	Execution
Installation preparation	15 min	Technician
Terminate remaining sessions	5 min	Technician
Complete installation of service packs or patches	15 min	Technician
Postprocessing	10 min	Technician

A maximum of 60 installations will be performed during the five-year utilization period.

Activity	Time expenditure per server	Execution
Planned patch installation	2 700 min	Technician

In addition it is assumed that one reserve server will be provided so that users can continue their work if one server requires installations or patches outside of the planned period.

If a patch has to be installed so soon that waiting until the planned downtime or the end of the workday is not possible, all users who are currently working on that terminal server have to be informed about that. The users then have to finish their session and can log onto another server immediately. This causes a work loss of 15 minutes for the users. A prerequisite for this is that all hosted applications are available on all terminal servers.

Activity	Time expenditure per activity	Execution
Inform user	5 min	Technician
Inform user	5 min	User
End session	5 min	User
Log onto new session	5 min	User
Prepare installation	15 min	Technician
Terminate remaining sessions	5 min	Technician
Complete installation of the service packs or patches	15 min	Technician
Postprocessing	10 min	Technician

It is assumed that an unplanned installation of patches or service packs that lead to work losses as described are only necessary once per year. Per year, 20 users are affected per terminal server which means that a factor of 100 results for all above listed time expenditures of the users given a five year utilization period.

Activity	Time expenditure per activity	Execution
Unplanned patch installation	250 min	Technician
Unplanned patch installation	2 625 min	User

4.3.8.3.3Installation of software

Aside from the initial installation, software always has to be installed when it is to be provided to a single user or a group for the first time.

Software that is to be installed on a terminal server not only includes applications but also the corresponding drivers in case local printers are used.

Server-side software installations cannot be considered in this cost model. Following will be some comments on the complexity of this issue.

If the software is well known, its terminal server compatibility is proven, and the exact installation process is documented, the installation can be performed. An additional prerequisite is also the successful testing of the compatibility with the other software that also runs on the terminal server. In certain circumstances, different software packages require different versions of a runtime library and, thus, exclude each other. This problem prohibits the use of the software on the terminal server.

According to the operating concept, this means that the installation can only occur if regular downtime is planned and announced. Depending on the configuration of the entire server farm, the software has to be installed on all terminal servers simultaneously so that the availability remains in the case of a

breakdown or a planned operational break for maintenance and/or service pack installation.

If the software to be installed is not well known and the terminal compatibility is not proven, the software has to be tested.

Evaluation

The evaluation process should explain whether the software will even run on the terminal server, how it is installed, and which resources in terms of CPU, main memory, and hard drive space are required for its operation. Usually, this necessitates research with the manufacturer and in white papers for the software on one hand and a test installation on the other hand.

Such an evaluation is necessary once for every version of the software and in exceptional cases for significant changes of the terminal software. The time requirements for such an evaluation process are known based on experience values and can be deducted from the experience of the IT management of Fraunhofer UMSICHT.

Activity	Time expenditure per activity	Execution
Research	60 min	Technician
Test installation	180 min	Technician
Documentation of the results	60 min	Technician

These concrete values are very dependent on the experience values of individual employees who are very experienced with the installation of applications on terminal servers. It should therefore be checked whether these values can be arbitrarily transferred to other institutes. If the appropriate experience does not exist, the required effort can easily increase by a factor of ten.

In addition to this expenditure, the costs for the necessary, dedicated test hardware on which the test installation can be performed have to be considered. The amount of the costs for this hardware and the licenses of the test environment and how they should be assigned to the specific evaluation and each workstation are currently unclear.

In addition, it has to be cleared up in every case whether the license agreement of the manufacturer even allows the installation and use of the software on the terminal server or how many of them are needed in such a case.

The risk exists that the expenditure for the evaluation and the costs for licensing of smaller installations can increase unproportionally and unreasonably under unfavorable conditions. This can make the whole project uneconomical.

When software is to be made available in an otherwise intensively used terminal server environment with many active servers for few employees that only work via Thin Client, it has to be made available on all servers in accordance with the recommendations in the emergency and maintenance plan. Depending on the terms of the license, it can occur that in certain circumstances significantly more licenses have to be acquired than would ever be used simultaneously. In the extreme case, as many licenses per server as the number of users who are to use the program. Given five users interested in the special application and ten servers, this could mean up to 50 licenses instead of five licenses for local installation.

In such cases, the availability has to be decreased or the terminal server farm has to be grouped by applications and divided up.

Additionally, it is currently unclear how the costs for the evaluation process should be judged and how they should be allocated to individual PCs, departments, or institutes. Neither the use of costs-by-cause principle, nor would a general allocation be appropriate in the context of this cost model or lead to sensible results. Mainly, the costs per workstation would be dependent on how much software has to be evaluated and then at how many workstations it would be used. This might even be difficult to calculate on an institute-level because the number of users can change later. Since the results of an evaluation should be centrally collected and generated to be available to all institutes, it could theoretically result in a decrease of the calculated costs because other institutes are using them as well. An allocation of the costs to the first user of this software also does not meet the goal of an appropriate cost distribution because as long as no internal service accounting between the departments and the IT-department on one hand and between departments of different institutes on the other hand the IT departments that perform the evaluation can only sit on the costs. Conversely, the people who wait with the evaluation will be better off – maybe someone else will do it. The continuation of this thought leads to IT departments refraining from using software that requires evaluation and, as a result, tends to use workstation PCs in favor of Thin Clients.

Therefore, it is suggested to find a central, institute internal, and institute-to-institute, practical solution.

Installation

It is certainly possible to estimate the expenditure for a single software installation. Thus, a single installation takes approximately 90 minutes.

Activity	Time expenditure per activity	Execution
Prepare installation	15 min	Technician
Terminate remaining sessions	5 min	Technician
Perform installation	60 min	Technician
Postprocessing	10 min	Technician

This time expenditure is only incurred once per terminal server during the first installation – given that no automated software distribution is employed. In order to determine the proportional costs for a software installation per workstation, how many different software packages are to be installed in total for each has to be clarified?

It cannot be assumed that 150 Thin Clients that require two software packages each outside of the standard equipment results in 300 different software installations. If that was the case and every installation had to be performed on ten terminal servers, it would result in the alarming sum of 3,000 installations in five years or 2.8 installations per workday.

The questions of how many already installed programs can be made available by simply adding them to a group and how many different installations are still necessary after, are also not easy to answer because the breadth of the software spectrum used at an institute is not known.

Calculation model

In accordance with the assumptions of this cost model, the implementation of Thin Clients is calculated under the assumption that only a standard workstation is needed. Therefore, the additional evaluation and installation of software on the server is not considered further in this model and not allocated to the Clients. Instead, the simplified assumption is made that all necessary software is already installed on the server since the initial installation and that it only has to be released.

4.3.8.3.4 Energy costs

The operation of a server requires much more electricity than the operation of a workstation PC. Aside from the constant availability (24x7, 365 days per year), the reasons for that are also the high electricity consumption of the components such as CPUs, large RAM, and quickly rotating hard drives. Added to that is the electricity consumption for cooling.

Calculation model

A typical terminal server of Fraunhofer UMSICHT with two redundant 460 W power supplies shows a peak power consumption of up to 350 W. The average over 24 hours is about 247 W. Off the job the load is lower. Therefore the average energy consumption decreases to 215 W. These values have to be doubled because of air conditioning. Given a price of 0.15 € per kWh this sums up to 3 078,54 € over five years.

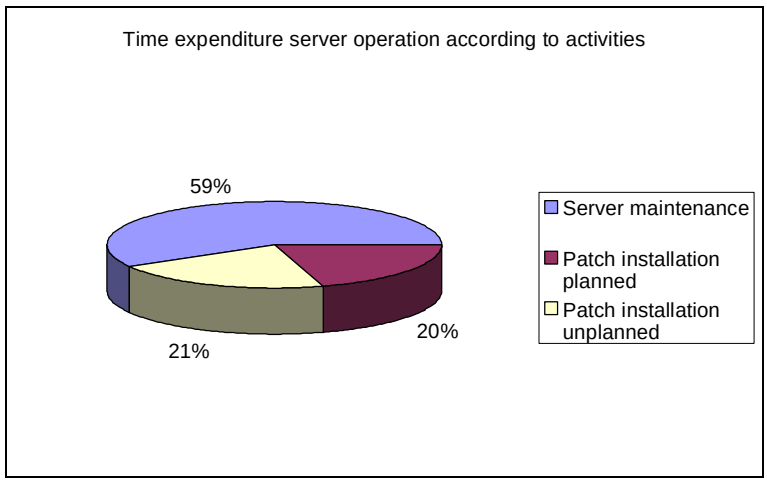
	Anzahl Arbeitstage pro Jahr	Watt	Preis (5 Jahre)
Energiekosten Betrieb	220	494	1 956.24 €
Energiekosten freie Zeit	145	430	1 122.30 €
Gesamt			**3 078.54 €**

4.3.8.4 Evaluation of operating costs

Description	Duration	Costs
Server maintenance	7 800 min	4 241.97 €
Planned patch installation	2 700 min	1 468.37 €
Unplanned patch installation	2 875 min	1 980.84 €
Energy costs		3 078.54 €
Total	**13 375 min**	**10 769.72 €**

The 13,375 minutes equals approximately 28.5 workdays over the entire utilization period or 5.8 workdays per years.

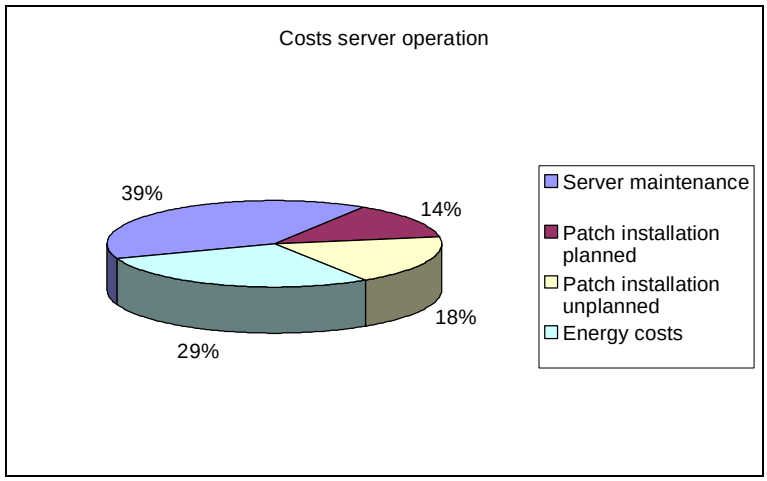
For the energy costs, electricity costs for air conditioning also have to be considered.



The server maintenance is calculated in the cost model assuming six minutes per workday. Its tasks include the checking of event logs, log files, performance

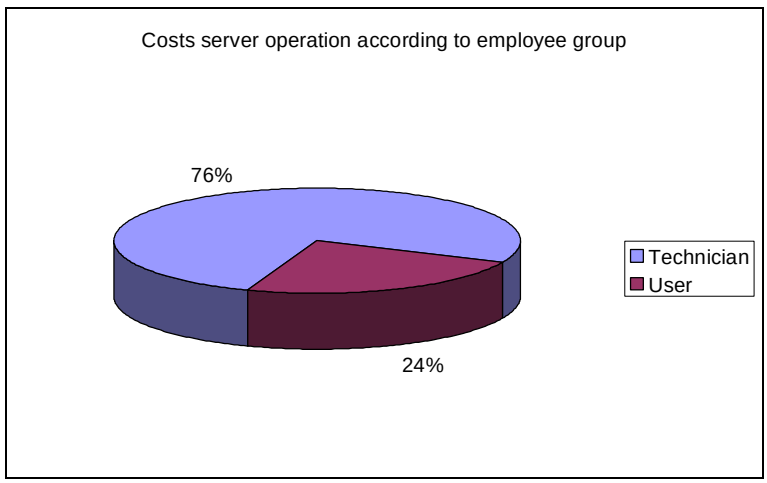
counters, etc. This low time requirement is only achievable with appropriate server management tools.

41 % of the entire time expenditure and 32 % of the entire operating costs are associated with the installation of updates, service packs, and patches.



Employee group	Duration	Costs
Technician	10 750 min	5 846.30 €
User	2625 min	1 844.88 €
Total	**13 375 min**	**7 691.18 €**

The time expenditure of the users for server operation is associated exclusively with work loss during unplanned maintenance.



4.3.8.5 Decommissioning

After the utilization period of five years, the terminal server is decommissioned. Although further use is possible, it is not considered here.

The first tasks of decommissioning encompass the deleting of the hard drives according to the IT security handbook, the updating of inventory lists and license documentation, and the disassembly from the 19" rack and storage until the final scrapping.

Another aspect of the decommissioning is the processing of the official decommissioning documentation which has to be processed by the IT management and the purchasing personnel.

Calculation model

The formatting of the three hard drives that will also be decommissioned takes about 180 minutes. Since this process can partially proceed unmonitored, a time expenditure of 30 minutes is applied to the cost model.

The server that is to be disposed of has to be stored. Here, a time requirement of ten minutes is calculated per server.

Activity	Time expenditure per activity	Execution
Update inventory list	10 min	Technician
Format hard drive	30 min	Technician
Decommissioning documentation	10 min	Technician
Decommissioning documentation	10 min	Purchasing manager
Disassembly from 19" rack	60 min	Technician
Storage	10 min	Technician

Description	Time expenditure per server	Execution
Decommissioning	120 min	Technician
Decommissioning	10 min	Purchasing manager

Added to that are the disposal costs for the electronic scrap which is currently paid based on weight. A cost of 75 € per server is assumed for this cost model.

Description	Costs per server	
Disposal costs	75 €	-

4.3.9 Cumulative cost evaluation

The costs for the operation of Server Based Computing are composed of the cost for the client and server side. In order to determine the total costs per

client, the established server costs are distributed onto the number of users who are assumed to work on the server. This is currently 35 users per terminal server.

For the client utilization, four types of operation need to be distinguished that have a significant influence on the total costs.

- All software will be used through a Thin Client on one or more terminal servers. The costs are lowest here also in comparison to workstation PCs.
- Standard software will be user via the terminal server and specialty software is used on a workstation PC. In this case, it is expected that the costs for the acquisition and operation of the PCs will increase slightly compared to the PC cost model. The reasons are the unchanged support requirement and acquisition costs on one hand and the additional proportionally allocated server costs.
- Specialty software is provided via the terminal server and a standard workstation through the local PC. This variant can create cost advantages for a business-wide provision of solutions for a relatively small circle of users especially at different business locations. However, not only do the costs for the acquisition and operation of a workstation PC on the Client-side remain unchanged, but also the total costs increase due to the expenses for the server.
- A combination of the three previously mentioned variants.

In this cost model, the first mentioned case is evaluated in which the software is exclusively provided by the terminal server and used with the help of a Thin Client.

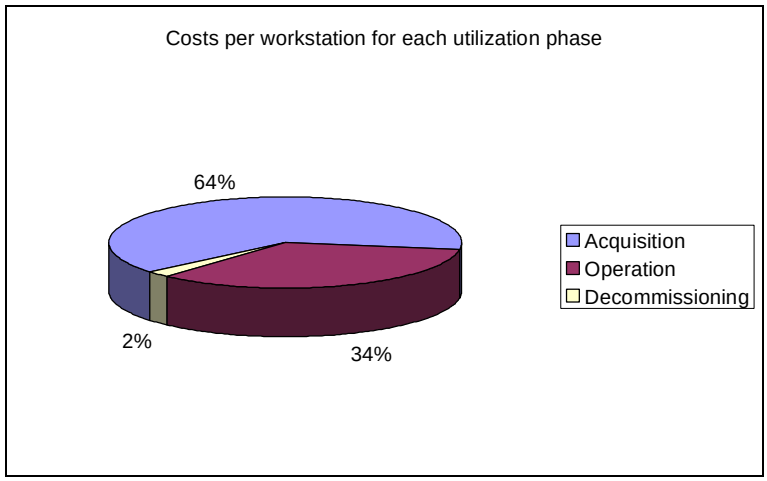
In this case, fixed-step costs can be incurred from the necessary acquisition and operation of additional servers. The costs for a server are the same whether one or 35 users work on it. This will be ignored for the evaluation of the total costs for reasons of simplification.

Number of users	Server costs	Client costs	Per workstation
35	30.196.31 €	37 981.38 €	2 089.51 €
70	45.294.46 €	75 962.77 €	1 838.43 €
105	60.392.61 €	113 944.15 €	1 754.74 €
140	75.490.76 €	151 925.54 €	1 712.89 €
175	90.588.92 €	189 906.92 €	1 687.78 €
210	105.687.07 €	227 888.31 €	1 671.04 €
245	120.785.22 €	265 869.69 €	1 659.09 €
280	135.883.38 €	303 851.07 €	1 650.12 €
315	150.981.53 €	341 832.46 €	1 643.14 €
350	166.079.68 €	379 813.84 €	1 637.56 €

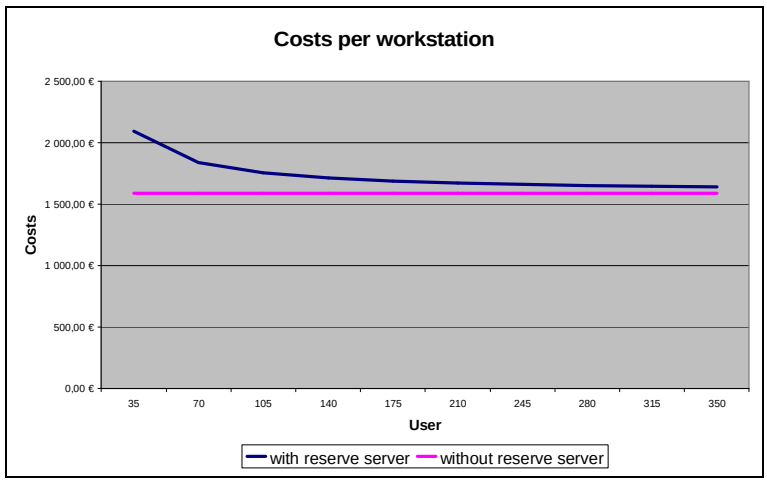
Without a reserve server the costs per workstation would be a constant 1 587,35 €.

Expenditure per workstation	Time	Costs
Acquisition	376 min	1 007.82 €
Operation	707 min	544.19 €
Decommissioning	54 min	35.33 €
Total	**1 137 min**	**1 587.35 €**

The table shows the distribution of the cumulative costs per workstation in each utilization phase based on a calculation without the reserve server.



The diagram shows the percentage distribution of the total costs for each utilization period.



The diagram shows the costs development per workstation for an increasing number of users. At the same time, it shows how the costs with and without a reserve server converge.

Reserve server

In strict business terms, the reserve server is only profitable when the expected costs during work loss are higher than the costs for the additional reserve server.

Such a complete outage can occur when a server fails and the remaining servers cannot absorb the work of the server that is down. If all the software used through the terminal servers is equally provided on all terminal servers, this case can only occur when only a single terminal server is utilized and it fails. In all other cases, the remaining terminal servers should theoretically be able to take over the tasks at the expense of response time behavior and, thus, at the expense of the users. However, the possibilities for this are quite limited because the server systems recommended in this cost model in the server sizing section have limited over-capacity. A server that previously served 35 users and reached a server load of 80% to accomplish that could potentially serve five additional users for a short time but not ten, 15, or even 20 additional users without resulting in significant deterioration in usability for all users.

When determining whether or not to use a reserve server, the following costs should be considered.

- 30 minute outage per year costs 105.42 € per user over five years
- 120 minute outage per year costs 421.69 € per user over five years
- 480 minute outage per year costs 1,686.75 € per user over five years

Number of users	Client costs with reserve server	Client costs without reserve server	Difference	30 min outage time	120 min outage time	480 min outage time
35	2 089.51 €	1 587.35 €	502.17	396.74	80.48	-1 184.58
70	1 838.43 €	1 587.35 €	251.08	145.66	-170.60	-1 435.66
105	1 754.74 €	1 587.35 €	167.39	61.97	-254.30	-1 519.36
140	1 712.89 €	1 587.35 €	125.54	20.12	-296.15	-1 561.21
175	1 687.78 €	1 587.35 €	100.43	-4.99	-321.25	-1 586.31
210	1 671.04 €	1 587.35 €	83.69	-21.73	-337.99	-1 603.05
245	1 659.09 €	1 587.35 €	71.74	-33.68	-349.95	-1 615.01
280	1 650.12 €	1 587.35 €	62.77	-42.65	-358.92	-1 623.98
315	1 643.14 €	1 587.35 €	55.80	-49.63	-365.89	-1 630.95
350	1 637.56 €	1 587.35 €	50.22	-55.21	-371.47	-1 636.53

All data (Exception: Column "Number of users") shows amounts in EURO currency (€) and gives costs per user over a time period of five years.

The table shows that, given the outage of a terminal server, already no money is saved for 70 users and a work loss of two hours per year but that costs are incurred instead. In this size category it also means that either 35 users cannot

work at all or that the remaining two servers will be overloaded and, thus, have a detrimental effect on all users.

From a technical point of view, it is actually less the CPU performance that is the critical factor when it comes to it but rather the insufficient main memory that forces to operating system to use the hard drive for expanded memory.

However, when considering a reserve server, it should be emphasized that not only the quantifiable, monetary arguments need to be regarded, but also the qualitative arguments need to be weighed. The personal experience of a Thin Client or a terminal server outage is subjectively experienced as more aggravating by the user than an equally long outage of the personal workstation PC and cannot always be rationally understood. This significantly increases the initially expected skeptic about Server Based Computing and can lead to open rejection. In the case of transferring server load to other terminal servers, this effect affects all users in the same amount as long as the work deterioration from the overload is significant.

4.3.10 Recommendations

The given cost model was developed with the help of various assumptions. The assumptions concern included parameters such as prices, frequency of the occurrence of certain events, or the duration of certain activities, or personnel costs. Additional assumptions encompass the typical sequence of certain activities or the employees involved in them. Before the calculation model is used to make decisions for or against Server Based Computing in general or a specific economic decision in detail, it is very important to evaluate whether the established boundary conditions are accurate for specific cases.

The following should be checked especially:

- Are the organizational procedures in my institute similar to those in the calculation model or are they completely different?
- Does the category of the users of a standard workstation coincide with the Medium User group, or am I mostly dealing with other users in my institute with consistently higher or lower requirements?
- Do I put an emphasis on the topic availability?
- Are my users mostly disciplined users or do they change the system configuration themselves at every opportunity?
- Are my workstations mainly mobile and, therefore, equipped with notebooks or are normal workstation PCs used predominantly?
- Are the assumed personnel costs for my institute correct?
- Are the purchase prices for the hardware still up to date?

When in doubt, Fraunhofer UMSICHT is always available to help adapt the evaluation to changed boundary conditions.

4.3.10.1Assert standardization

The largest benefit can be achieved by using Server Based Computing in combination with standardized workstations and the utilization of Thin Clients. This benefit which was only evaluated in terms of costs in this model also encompasses aspects of ergonomics (e.g. less fan noise and high frequency drive noises), data security, investment protection, and many more. These aspects should not be neglected when deciding for or against Server Based Computing.

Every IT responsible party considering Server Based Computing should check how many workstations would suffice with a strictly defined function scope and few standard software products. This evaluation should also include which workstations can be turned into that in the medium term using consolidation measures. The more homogeneous the software to be implemented and the smaller the diversity of the utilized products, the greater is the chance to identify sufficiently many workstation that could profit from switching to Server Based Computing. Starting at around 40 to 50 workstations, the implementation of SBC will have a positive impact on the total cost development in the medium term.

4.3.10.2Encourage motivation

The implementation of SBC is often encountered by skeptic or even open rejection. The reasons for that are diverse and cannot be rationally understood in part. Employees whose workstations are equipped with Thin Clients view these workstations as second class and, in many cases, interpret this as being valued less and as having a lower hierarchical position. The loss of the "personal" aspect of their PC and the lower control are experienced as paternalism.

Frequently used arguments against Thin Clients are the actual or pretended necessity for data exchange with local data carriers such as CD-ROM drives or disks. Furthermore, the argument that the damage from work loss caused, if all terminal servers were to fail, would be very large, whereas one could continue to work with local PCs. All arguments can be countered with technical solutions and corresponding concepts. In this context, it is important to prepare ahead of time, to actively deal with the most prevalent counter arguments, to prepare solutions, and to proactively inform the employees. In order to accomplish this, it can also be helpful to take advantage of group dynamic processes and to bring known opinion leaders, i.e. employees with influence over their colleagues, on board early and to convince them.

It is also important to ensure that neither the introduction nor the later operation of Thin Clients give reason to confirm prejudices from before the introduction. A positive climate has to be created that allows the affected employees to confront the topic of Server Based Computing without preoccupation and prejudice. Important aspects to achieve that are the availability and the response behavior of the terminal server. These are very critical factors and insufficient performance quickly leads to rejection. Therefore, the servers have to be dimensioned adequately to meet the expected load demands. The test group with whom the process is started will have a significant influence with their early opinion on the attitude of others on the topic of SBC. Using servers that are insufficiently dimensioned or using too few servers to start operation and then to add based on demand might seem sensible or like a good strategy in many cases, but it should be avoided for the introduction of SBC due to the reasons mentioned above.

It is possible to impress the user and motivate them to make the switch as has been successfully proven by institutes of the Fraunhofer Society through superior performance of the terminal servers even compared to workstation PCs. However, there are also other possibilities. For example, the use of modern or exclusive software packages such as the newest Office version, a route planning system, or rare and expensive specialty encyclopedias could be offered via terminal server exclusively or significantly earlier.

Another alternative is the combination of the provision of Thin Clients together with other components such as TFT-LCD monitors or external drives for CD-ROM or disks in order to solve the problem of local data exchange.

5 Appendix

Following are the questionnaires with which the database for PC specific support requirements was generated.

5.1 Questionnaire "Unmanaged PC"

Questions		Last week	Last 3 months	Last year
1	How much time in total is spent on Client and user support?			
2	How many PC reinstallations were performed that did not involve a new acquisition (e.g. due to hardware failure, virus infection, driver problems, regular bluescreens, user mistakes)?			
3	How long does such a reinstallation take on average (incl. search for data carries, completion, and functionality test)?			
4	How long does the preparation take for that (search for data carriers, information research, etc.)?			
5	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
6	How many local software installations (without patches) were performed?			
7	How long does a software installation take on average (incl. search for possible data carriers, completion, functionality test)?			
8	How long does the preparation take for that (search for data carriers, information research, etc.)?			
9	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
10	How many service packs, hotfixes, patches, etc. were installed?			
11	How long does the installation of a service pack, hotfix, patch take per workstation PC?			
12	How long does the preparation take for that (search for data carriers, information research, etc.)?			
13	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
14	How many hardware additions were performed (e.g. CD-ROM, RAM, larger hard drive)?			
15	How long does a single hardware addition take on average?			
16	How long does the preparation take for that (search for data carriers, information research, etc.)?			
17	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
18	How many workstation PCs were moved during relocations?			
19	How much time is required for moving a workstation PC during relocation?			

5.2 Questionnaire "Managed PC"

Questions (Client)		Last week	Last 3 months	Last year
1	How much time in total is spent on Client and user support?			
2	How many PC reinstallations were performed that did not involve a new acquisition (e.g. due to hardware failure, virus infection, driver problems, regular bluescreens, user mistakes)?			
3a	How long does such a reinstallation take on average (actual time)?			
3b	How much time does the administrator spend on a reinstallation on average?			
4	How long does the preparation take for that (Checking of name/address, research of information, etc.)			
5	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
6a	How many local software installations (without patches) were performed?			
6b	How many of them manually, which means without CCM?			
7a	How long does a software installation take with CCM on average (incl. search for possible data carriers, completion, functionality test)?			
7b	How long does one take without CCM?			
8	How long does the preparation take for that (only manual installations) (search for data carriers, information research, etc.)			
9	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
10	How many service packs, hotfixes, patches, etc. were installed?			
11	How long does the installation of a service pack, hotfix, patch take per workstation PC?			
12	How many hardware additions were performed (e.g. CD-ROM, RAM, larger hard drive)?			
13	How long does a single hardware addition take on average?			
14	How long does the preparation take for that (search for data carriers, information research, etc.)?			
15	How long does the postprocessing take (updating Help Desk databank, inventory data, etc.)?			
16	How many workstation PCs were moved during relocations?			
17	How much time is required for moving a workstation PC during relocation?			

Questions (Server)		Last week	Last 3 months	Last year
1	Support expenditure for CCM-Server (maintenance, regular monitoring)?			
2	How long does the package configuration / scripting take for an initial installation?			
2a	Operating system			
2b	Drivers			
2c	Applications			
3	Support expenditure for SUS/WSUS (maintenance, regular monitoring)?			
4	Support expenditure for EPO (maintenance, regular monitoring)?			

Trademarks

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