Windows or Linux?

Evaluate the Total Cost of Ownership Before You Decide

Abstract

In these challenging economic times, IT managers looking to reduce budgets have naturally been attracted to Linux because there are little or no costs involved in acquiring the software. But software licensing costs are only a fraction of the costs associated with an IT operating system. Just how well does Linux compare with Windows economically when all of the costs of migrating, operating and maintaining each platform under real-world conditions are considered? Which is the lower-cost platform over the life cycle of the system?

Microsoft conducted total cost of ownership (TCO) studies worldwide with 16 business organizations. The studies compare the relative lifecycle costs of Microsoft® Windows® and Linux client-server systems using industry-standard TCO measurement tools from Gartner Inc. Server and desktop expenses were collected and normalized to a single per-desktop cost.

The research found that the overall costs of the Linux solution, which includes application integration, ongoing infrastructure management and support, negates the one-time advantage of "free" Linux software. Linux adds significantly to operational complexity and the costs associated with systems management. Linux requires more staffing resources and effort to match the reliability, availability and scalability of high-end Windows installations. Users must also purchase high-availability add-ons and support services from third parties, which increase costs and system complexity.

When all the lifecycle costs were included, Windows achieved TCO values that ranged from 5 to 28 percent lower than Linux in all of the companies studied. On average, implementing a Windows upgrade produced a lower TCO of $398 normalized per desktop than Linux. While TCO is only one among many factors that need to be evaluated when selecting an enterprise operating system, it is a significant one.

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Executive Summary

With money for budgets scarce, IT managers are attracted to the potential costs savings claimed by Linux. But software licensing represents only a small percentage of the total cost of operating and maintaining an enterprise system. (See Exhibits 1 and 2.) The economics case of Linux compared with Windows is not compelling when all direct and indirect costs and service levels are considered over the lifecycle of the system.

Microsoft performed studies of 16 companies—most of which use older versions of Windows—that were considering a Linux-versus-Microsoft upgrade as a way to reduce costs. Microsoft Consulting Services, which has performed more than 1,000 such studies, used the industry-standard measurement tool from Gartner Inc. to determine the total cost of ownership (TCO) of comparable implementations of Windows and Linux client-server systems. The study included organizations from financial services, municipal governments, retail and manufacturing industries. Server and desktop expenses were collected and normalized to a single per-desktop cost. For these studies, file/print server, Web server, and security/utility server costs were measured as well as operating system and Microsoft Office productivity suite costs on the desktop side.

TCO is only one factor among many others that should be considered by IT professionals in making an enterprise system decision. Other factors, such as risk, business alignment, business benefits, and flexibility are also essential. However, at a time when companies are strongly focusing on their bottom line, TCO is an important measure of how efficiently IT activities are functioning. TCO is also much easier to quantify than these other areas of value.

IT buyers today are looking for solutions with built-in value that make IT easy to use, deploy, implement, maintain and expand to meet evolving business needs. The studies reported in this paper demonstrate clearly that Microsoft Windows product offerings require less effort, customization and maintenance, which results in the more cost-effective solution.

The Gartner TCO model consists of five basic categories. Three of the categories "hardware and software, operations, and administration" are direct costs that come out of the enterprise's budget. The other two categories, end-user operations and downtime, are indirect costs. They reflect lost productivity of the end user and do not appear directly in any part of the company budget.

Exhibit 1: TCO by Cost Category

Hardware 10%
Downtime 5%
Software 8%
End-user Operations 40%
IT Operations 25%
Administration 12%
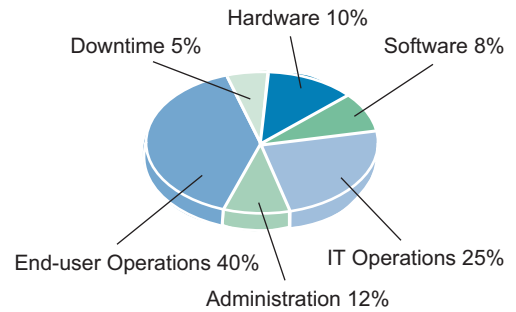
Exhibit 2: Typical TCO Breakdown

Component	% of TCO
Hardware	10%
Software - Operating system - Packaged applications	8%
IT Operations Cost of IT labor for: - Hardware deployments - Software deployments - Tier 0,1,2,3 support - Backup and restore - System maintenance	25%
Administration - Training courseware - Procurement activities - Vendor management	12%
End-user Operations - Peer/self support - Formal learning - Data management - Application configuration	40%
Downtime - Scheduled upgrades - Unplanned system failures	5%

Hardware and software are relatively minor TCO components compared to the cost of IT and end-user operations.

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When the TCO of the IT solution alternatives was calculated, the studies revealed that Linux solutions are more expensive over the long run. In all of the organizations studied, the Microsoft solution achieved a lower TCO than Linux by as much as 28 percent. On average, implementing a Windows upgrade had a $398 lower per-desktop TCO than Linux. Key factors influencing the TCO differential in favor of Windows-based solutions were:

- Lower complexity levels and the ability to leverage more best practices with the Windows platform

- Lack of available, dependable and affordable management tools for Linux to ensure minimal user interruption and systems maintenance labor costs

- Risk associated with Linux falling short of implementation goals

Complexity and Best Practices

IT systems have an intrinsic complexity driven by the types of tasks users must perform and the diversity and configuration of the system's hardware and software components. The Gartner TCO model captures the complexity of the business environment being supported within the technology ownership costs. A high degree of complexity impacts the ability of the organization to implement industry-leading management and operational procedures, called best practices, which in turn affect the overall TCO.

In the studies, the costs of IT and end-user operations were higher for the Linux scenario because Linux lacks features that enable the use of the best practices associated with systems integration, modification and management. This adds significantly to operational complexity and costs.

For Linux, the single biggest factor inflating the TCO was the additional manpower required for IT and end-user operations. Staffing costs are directly related to the routine time and effort required on the part of IT staff to manage, maintain, troubleshoot and restore the system operations. On average, an IT operations staff can handle 14 percent more clients in a Windows environment than in a Linux environment. (See Exhibits 3 and 4.) For end-user operations, the cost is the lost productivity of users when they are required to partially maintain their own systems. End-user costs are reduced by easier-to-use applications and by the IT department (IT operations) doing a better job of centrally managing systems.

Exhibit 3: Ratio of Desktops to IT Personnel by Geographic Region

Regional Avg.	Windows	Linux	Difference
North America	105	93	11.5%
Europe	125	106	15.2%
Asia	77	62	19.5%
Worldwide	110	94	14.5%

The ratio of desktops to IT staffers varied significantly by geographic region. In general, the regions that had the highest ratios provided the lowest level of services to users. Thus, end-user operations costs were generally higher for these regions.

Exhibit 4: Ratio of Desktops to IT Personnel by Industry

Industry Avg.	Windows	Linux	Difference
Financial	56	52	7.1%
Government	122	99	18.9%
Retail	138	120	13.0%
Other	115	100	13.0%
Combined	110	94	14.5%

The ratio of desktops to IT staffers varied significantly by industry. In general, organizations with more expensive user communities spent more on IT staff (FTEs) to reduce the burden on users. The implementation of best practices helps an organization to make a small investment in IT operations to yield a larger savings in end-user operations. Many best practices are tied to the capabilities of the IT infrastructure.

Microsoft Active Directory

The Microsoft Active Directory directory service allows organizations to centrally manage and share information about network resources and users while acting as the central authority for network security. In addition to providing comprehensive directory services to a Windows environment, Active Directory is designed to be a consolidation point for isolating, migrating, centrally managing, and reducing the number of directories that organizations require.

Management Tools

Microsoft Windows client-server products include a set of tools that enhance best practice management. These tools have to be purchased for a Linux environment. For example, some customers were considering purchasing IBM Tivoli to replace functionality that Windows provides through the Microsoft Active Directory® directory service. The cost of third-party

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software actually drove the software licensing cost for Linux higher than for Windows in three of the studies.

Risks

Although the Gartner TCO tool does not measure risk, most of the organizations in these studies modeled risk as the financial impact of falling short of desired outcomes in the planned IT implementation.

In the majority of the studies, the risks of deploying Linux-based solutions were evaluated to be significantly higher than the Windows-based alternatives, largely due to lack of maturity in the Linux platform and available management tools and applicable in-house expertise. This analysis often resulted in additional implementation labor costs being added to the Linux scenario. This is a significant finding because labor costs are the most highly variable component of implementation costs, whereas hardware and software are known entities.

Exhibit 5: Platform Decisions Based on Microsoft TCO Studies

Stated Direction	Before TCO Study	After TCO Study
Planned on Linux	4	1
Probably Linux	3	1
Open	6	4
Probably Windows	2	2
Planned on Windows	1	8

The TCO studies had a significant impact on customer decision making. It should be noted that the study process was as valuable as the actual TCO numbers. By doing the studies, customers became more aware of the actual IT costs in their environment.

As a result of the TCO exercise, several companies decided to proceed with Windows software rather than a Linux-based implementation. As Exhibit 5 indicates, after the exercise, only one company planned to continue with Linux. In fact, one company that was already implementing Linux scrapped the project after going through the cost analysis with Microsoft. This customer is now upgrading its Windows infrastructure.

Summary Results: ROI and TCO

In addition to calculating TCO for the 16 companies studied, the consultants also performed standard return on investment (ROI) measurements. ROI and TCO metrics are related but are used to measure different things. ROI is used to evaluate a specific project, while TCO provides a cost profile for a technology. While ROI is tactical for a single project, TCO is part of a collection of metrics used for strategic decision making.

Return on Investment

ROI is a broad term used to describe a number of metrics that are used to evaluate a set of cash flows. In the majority of studies done for this paper, four year's worth of cash flows were considered and evaluated with net present value (NPV), internal rate of return (IRR) and project payback period.

It should be noted that TCO is limited in that it considers only cost reduction benefits and ignores value gained or lost to the business. For this reason, ROI in this report should be more appropriately dubbed a partial return on investment since business benefits such as user productivity and IT flexibility are not part of the TCO equation.

TCO also differs from ROI in that it is stateless—it considers past, current and future costs as if each were of equal value. A TCO metric is generated by estimating every cost from the day a project is conceived until the day when the technology is retired. This single number is then divided by the number of years in the project to provide an annualized figure. TCO metrics sometimes confuse people since the monies already spent are included in a TCO estimate for a technology that is midway through its lifespan.

This is very different from ROI, where only current and future costs are considered. In ROI, costs that have already occurred are considered sunk and irrelevant and are excluded from the analysis. ROI answers the question, "What should I do going forward?" TCO answers the question, "Which platform is the least expensive to operate?"

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The 16 customers considered in this paper had three distinct options available to them. They could migrate their current Windows environment to Linux, upgrade their current environment to Windows XP or do nothing. In order to determine the best course of action, an ROI analysis was required.

In 13 of the 16 studies, an ROI analysis indicated that an upgrade to Windows XP would be the most cost-effective solution. For the remaining three studies, ROI suggested that the existing environment should be utilized a little longer before upgrading. None of the studies showed positive ROI for a Linux migration. Exhibit 6 provides average TCO and ROI metrics for the Windows upgrade and Linux migration scenarios.

Exhibit 6: Average ROI and TCO

Per Desktop	Windows Upgrade	Linux Migration	Difference
NPV	$134	-$49	N/A
TCO	$3,693	$4,210	14%

In all studies performed for this report, Linux failed to show a positive ROI for a migration from Windows. In all cases, it was in the customer's best interest to either utilize their existing Windows infrastructure a little longer or to migrate to Windows XP. Windows XP makes the most sense when Active Directory is in place to manage it.

TCO Insights

TCO calculations involve a complex set of data that can vary widely and depend on a particular implementation scenario. The TCO for the Linux solution was higher in all studies; it ranged from 5 to 30 percent more than for Windows, with an average of 14 percent more.

In reviewing the cost categories of the TCO calculations, some factors clearly had a larger impact on the outcome than others.
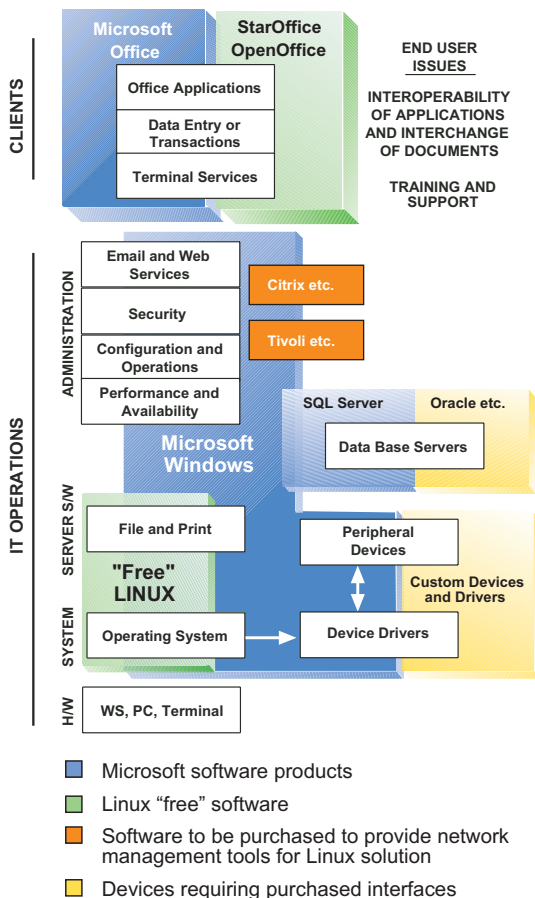
Hardware and Software

The hardware cost makes up 9 to 10 percent of the TCO. It consists of all the capital expenditures relating to hardware assets covering end users and business functions as well as software licensing costs that are bundled with the original equipment acquisition. Additional hardware costs for assets used by the IS staff to maintain the IS system (referred to as IS hardware) are also in this category. Hardware used by product organizations for development is not included.

There was very little—less than one percent—difference in the hardware costs between the Windows upgrade and the Linux solution. Basically, this is because both solutions are designed for the same types of hardware.

The software licensing cost makes up about 8 to 9 percent of the TCO. IT software systems include server and desktop software and all the necessary tools for monitoring network performance, managing configurations and security, e-mail and Web services, and supporting existing business applications and peripheral devices. The components of a typical IT environment are shown in Exhibit 7. The operating system is the heart of an enterprise information system, but it is not the only software licensing cost involved, or even the largest cost.

Exhibit 7

- Microsoft software products
- Linux "free" software
- Software to be purchased to provide network management tools for Linux solution
- Devices requiring purchased interfaces

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The average software licensing cost for the Windows upgrade was 4 percent more than for the Linux solution. This reflects the no-cost Linux licenses. However, because of the cost of additional software needed for the Linux solution to match the functionality of the Windows upgrade, the average software licensing costs are surprisingly close for the two solutions.

Factors that increased the Linux software licensing costs included:

- **Having to retrofit existing server/desktop applications.** In several situations, customized software development would be required to enable Linux to interface with existing business applications or specialized input devices.

- **Creating Linux device drivers for peripherals.** One of the retail companies had a number of older peripherals, some of which were customized for their environment and supported by Windows. Drivers for these devices did not exist for Linux and would have been very costly to develop and maintain. The cost of writing device drivers made the Linux option unfeasible.

- **The need to purchase management software.** If advanced client management was desired, the customer would need to purchase IBM Tivoli or some other vendor's management software. These software packages are expensive, especially when compared to the management tools that come built in with Windows. In the 16 studies done, the combination of the Active Directory directory service and the Windows XP client had the most significant effect on TCO.

  Microsoft also offers other management tools such as Microsoft System Management Server, Microsoft Operations Manager, and Microsoft Application Center that would further decrease TCO under the Gartner model. Some but not all of this functionality is available from various vendors for Linux. Most of the Linux applications come at significantly higher cost than their Microsoft counterparts.

- **Expensive workarounds for incompatible software.** Different client applications also add complexity to the environment. In a number of proposed Linux environments, client PCs would still have needed to run Windows applications from a Windows Terminal Server. This functionality was going to be supplied by running a Citrix client on the Linux PC and then having the user connect to Windows Terminal Server, which provides a complete Windows desktop where applications can be run. While meeting the business requirements, this solution is expensive because the customer must purchase a Windows client license to connect to Terminal Server, a Citrix license to allow the Linux PC to connect to the Windows server plus the added complexity of managing a Terminal Services environment. If this

Systems Management Server

Microsoft Systems Management Server provides detailed hardware inventory, software inventory and metering, software distribution and installation, and remote troubleshooting tools. These integrated features make Systems Management Server a powerful tool for reducing the cost of change and configuration management for Windows based desktop and server systems.

Microsoft Operations Manager

Microsoft Operations Manager is a set of management tools providing event and performance management for the Windows 2000 Server family of operating systems. MOM reduces TCO costs by monitoring IT systems, alerting administrators of potential problems before they occur and by taking proactive actions based on rules defined by IT Personnel.

Microsoft Application Center

Microsoft Application Center 2000 is the deployment and management tool for high-availability Web applications built on the Microsoft Windows 2000 operating system. Application Center 2000 makes managing groups of servers as simple as managing a single computer. Application Center reduces IT Operations and downtime costs.

Windows Terminal Services

Windows Terminal Server lets you deliver Windows-based applications, or the Windows desktop itself, to virtually any computing device—including those that cannot run Windows. When users run an application on Terminal Server, the application execution takes place on the server, and only keyboard, mouse and display information is transmitted over the network. Users see only their own individual sessions, which are managed transparently by the server operating system, and remain independent of any other client session.

Windows Terminal Services is critical for organizations running Linux clients that need access to Windows applications.
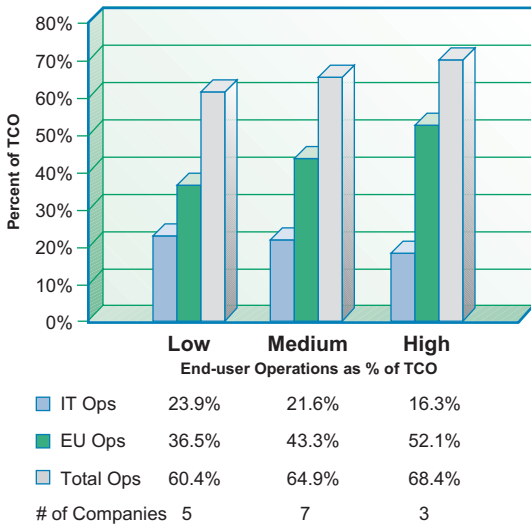
functionality is required on a large scale, the software licensing costs of the Linux solution will actually exceed that of Windows.

Operations

The most dramatic finding to emerge from the studies is that human costs are the largest portion of the TCO, roughly 80 percent.

Operations consist of IT operations (the staffing cost attributed to the IT department) and end-user operations (the time that users spend managing their own systems). Operations accounts for 54 to 68 percent of the TCO. (See Exhibits 8 and 9.)

There is also a strong correlation between the investment made in IT operations and the amount spent on end-user operations. Generally, organizations that spend more on IT operations and better leverage best practices dramatically reduce end-user operations costs. This reduction is enough to significantly reduce the overall operations contribution to the TCO. In other words, hardware and software are relatively fixed costs, so organizations can reduce overall costs most effectively by finding the optimal trade-off between IT operations and end-user operations costs. Best practices are the best way to alter this relationship.

In many studies that had the lowest end-user operations cost per client the IT department had the highest cost of IT operations per client. This can be measured by the ratio of IT operations cost per client to end-user operations cost per client. When this ratio was lowest (1.08), the total operations contribution to TCO was 54 percent. On the other end of the scale, when the ratio was highest (3.50), the operations contribution to the TCO was 68 percent.

Part of Windows value-add over Linux are features like the Active Directory directory service and Windows XP Group Policies. Organizations can use these features to more easily adopt best practices that provide large returns in end-user operations through a small investment in IT staffing. For example, by implementing Active Directory and Windows XP, the IT department can leverage Microsoft IntelliMirror® management technologies, which automatically backs up user documents through a process transparent to the user. This dramatically reduces lost data and removes the need for users to back up their own data. Eliminating that need reduces end-user operation costs. Therefore, a small investment in IntelliMirror in the IT department will yield much larger end-user operations cost savings.

IT Operations

IT operations costs make up 23 to 26 percent of the TCO. IT operations costs are the staffing costs attributed to the IT department to deploy and maintain the enterprise computing environment. They are measured in headcount at

Exhibit 8: Contribution of Operations Costs to TCO

	Low	Medium	High
IT Ops	23.9%	21.6%	16.3%
EU Ops	36.5%	43.3%	52.1%
Total Ops	60.4%	64.9%	68.4%
# of Companies	5	7	3

Low end-user operations cost related to higher IT operations spending and results in an overall lower cost of operations as a percent of the TCO.

Exhibit 9: Relationship of Operations Costs to TCO

	Low	Medium	High
Ratio of End-user Operations to IT Operations	1.08	2.25	3.50
% of TCO from Operations	54%	64%	68%

As the ratio of end user to IT operations costs increases, so does TCO. The implementation of best practices can be used to reduce this ratio and TCO in general. The ability to implement best practices is partially dependent on the capabilities of the IT systems and available management tools.

the full-time equivalence (FTE) rate. The IT operations staff performs many tasks, including service desk functions; application management; configuration management; disk, file and data management; security and virus protection; as well as fundamental maintenance and system support for installs, moves, adds, changes and removals of networks, systems and system components.

Without exception, the Linux solution was estimated to be significantly more costly to operate than the Windows upgrade, averaging 25 percent more.

Linux is at a disadvantage when compared to Windows in IT operations because of a lack of management tools. As part of the server operating system, Microsoft Windows includes features like the Active Directory directory service and the Microsoft Management Console (MMC), which make it easier to manage both servers and clients.

Microsoft Management Console

Microsoft Management Console makes it possible for a systems administrator to manage a wide range of IT assets from a single tool. MMC is a Windows-based multiple document interface (MDI) application. Application developers can extend the console by writing MMC snap-ins, which perform management tasks. This allows the MMC to be used for non-Microsoft applications. The end result is that the MMC will reduce TCO by giving IT personnel a comprehensive tool for managing all their Windows-based systems.

In addition to capabilities built into the core product, Microsoft offers a complete management suite, which includes products like Systems Management Server and Microsoft Operations Manager (MOM) and Microsoft Application Center. These products have a dramatic impact on TCO and are captured in the Gartner TCO model through best practice improvements. For Linux, management products are limited and are only available as expensive stand-alone products. This limits Linux's ability to leverage best practices to reduce IT operations costs.

By better leveraging best practices, Windows was able to achieve a higher ratio of desktops to administrators. The average desktop-to-administrator ratio for Windows was 110 and 94 for Linux. This represents a 14-percent improvement for Windows over Linux. (See Exhibits 8 and 9.)

End-User Operations

On average, end-user operations costs make up between 40 and 41 percent of the TCO. End-user operations account for the time that users spend managing their own systems. It includes such tasks as peer support, casual and formal learning, file and data management, and application development. It is calculated based on FTE, and the costs are incurred outside of the IT department. As noted earlier, there is a relationship between end-user and IT operations costs. A small increase in IT operations spending generally leads to a larger cost reduction in end-user operations. The ratio of IT to end-user operations costs is considered a good benchmark of IT competence at an organizational level.

Exhibit 10: End-User Operations Costs per Desktop by Geographic Region

Region Avg.	Windows	Linux	Difference
North America	$1,458	$1,489	2.0%
Europe	$1,625	$1,956	16.9%
Asia	$1,916	$2,070	7.4%
Worldwide	$1,639	$1,854	11.6%

End-user costs varied significantly by region and are tied to the investment made into the IT department through the implementation of best practices. In general, a small investment in IT will return a larger benefit in the form of reduced user operations costs.

The largest component of the total TCO value in 15 out of 16 studies was end-user operations costs. In all cases, the cost for a Linux system was equal to or greater than for Windows, ranging from 32 to 51 percent for Windows and from 31 to 59 percent for Linux. This cost is driven by users managing their own desktops. Not surprisingly, companies with the higher end-user cost percentages have the

Industry Avg.	Windows	Linux	Difference
Financial	$2,192	$2,512	12.7%
Government	$1,585	$1,961	19.1%
Retail	$1,189	$1,234	3.6%
Other	$1,627	$1,692	3.8%
Combined	$1,639	$1,854	11.6%

End user operations costs vary significantly by industry for two reasons. First, there is a wide variance in end-user salary levels. (Finance had the highest and retail the smallest). Second, organizations that had high end-user salary costs tended to implement more best practices and to deploy more IT resources to support the user community. The numbers in the table are acted on by both variables.

highest complexity factor, that is, the number of user desktops, applications and system configurations to support.

The contribution to the TCO of end-user operations was uniformly higher for the Linux solution than for the Windows upgrade, averaging 15 percent more. (See Exhibits 10 and 11.) Note that this did not include the document conversion numbers; if they are included, the average end-user operations cost for Linux is nearly twice that of the Windows upgrade.

Because the Windows suite of management tools enables the IT department to more efficiently manage the user environment, Windows reduces the end-user operations cost per client by more than 10 percent by reducing the amount of time users spend supporting themselves.

Administration

Administration costs make up 12 to 15 percent of the TCO. This category measures costs for peripheral services required to support a network environment, including corporate purchasing policies, asset management, procedures and personnel, as well creating and managing training materials for both the IS department and end-users. TCO is highest in the retail industry because of the number of remote locations that must be supported. The more locations, the more difficult asset management becomes.

The administrative cost averages 7 percent more for the Linux solution than for the Windows upgrade.

The administration costs for Windows were equivalent or lower than Linux in all cases, up to 33 percent less. This difference is related to reduced training requirements (that is, when end-users are familiar with Windows) and less complex vendor management.

Downtime

Downtime costs make up 3 to 5 percent of the TCO. Downtime, the time the system is not operating, is a function of scheduled system upgrades and changeovers as well as unscheduled events due to end-user interactions, hardware failures, operating system issues, application failures, network outages and security breaches. In the studies done, downtime costs were the highest in the financial services and government sectors.

Application Programming Interfaces

APIs have become the method by which vendors define the software interface to their products. The product could be a piece of hardware, a third-party library or even an operating system. APIs make it easier for software developers to build applications that interface with other vendors' products. In regards to downtime costs, well-defined APIs make it easier for software developers to build applications that can help manage IT resources. The better and the more numerous the tools, the greater the opportunity to reduce downtime through better management.

The downtime cost averages 46 percent more for the Linux solution than for the Windows solution.

If the impact of using best practices is not considered, Windows and Linux have comparable downtime. In 11 of the 16 studies, Windows pulled ahead of Linux in downtime because of better management practices and more mature server clustering. The most significant factor in reducing downtime was the ability to proactively manage servers and clients with advanced tools. Windows has built-in Application Programming Interfaces (APIs) that can be leveraged to monitor

hardware and software and identify problems before they occur. Windows also includes rudimentary tools such as Performance Monitor to leverage this API.

If more advanced or centralized monitoring is required, IT organizations can purchase products like Microsoft Operations Manager or a host of tools from firms like NetIQ. Linux has no comparable API or available monitoring process, so organizations are not able to proactively manage their IT assets to reduce downtime.

Impact of Complexity

The diverse range of components and processes required to operate an IT system—end-users, software and hardware—are captured in Gartner's complexity metrics. The metrics take into account the support requirements of an end-user organization and the hardware and software technology deployed in a distributed environment. Lower complexity equates to less cost in managing and maintaining the network and a lower TCO.

The three categories of complexity are:

- **End-user organization**, business functions performed and support (help desk services) required by end-users.

- **Software technology**, different kinds of application and system software that must be supported.

- **Hardware technology**, different kinds of hardware that must be supported.

Minimizing and managing complexity are two of the keys to successful cost containment in today's IT environments. Small changes in complexity can affect the TCO significantly. (See Exhibits 12 and 13.)

The superior numbers for Windows are a result of the fact that the Windows environment is both an integrated operating system and a suite of management tools.

A large component of complexity cost is trying to make a collection of software packages from various vendors work together. The Windows one-stop shopping approach gives it a significant advantage over Linux. Other components of complexity such as the number of foreign languages spoken at the service desk affect Linux and Windows equally.

Across different industries, the cost of IT operations as a percent of the total TCO increases with the complexity of the environment. (See Exhibit 14.) In these studies, the complexity value was lowest in the government sector

Exhibit 12: IT and End-User Operations Costs at Different Levels of Complexity

Complexity Level	% of TCO		% of TCO from IT & EU Operations
	IT Operations	End-user Operations	
Low	17%	44%	61%
Medium	22%	42%	64%
High	24%	37%	61%

Exhibit 13: Relationship Between Complexity and IT Operations Costs

IT Operations Cost per User	Complexity Level		
	Low	Medium	High
Windows	$577	$724	$1,519
Linux	$730	$882	$1,727

Exhibit 14: Complexity and Operations Costs by Industry

Operations Cost % of TCO — Compexity
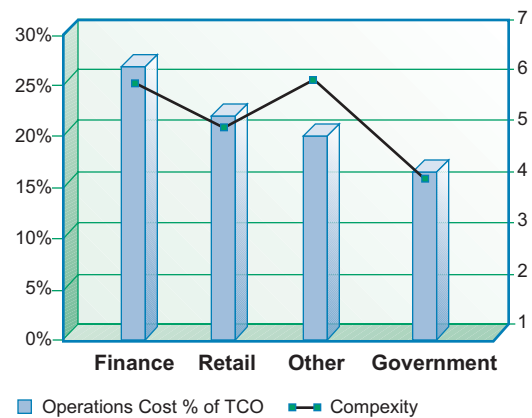
Complexity varied significantly by industry as some industries tended to follow a "best of breed" strategy, and others concentrated on more standardization. From a TCO perspective, a best of breed strategy comes at high cost.

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where clients do not run complex applications, and highest in the financial services category where a higher number of user applications and hardware are supported. In the Other category, the results were skewed by one company, in which a complex environment was very well managed.

Impact of Best Practices

Best practices are groups of tasks that contribute to the efficiency (cost/risk ratio) or effectiveness (service level) of a business discipline or process. They are a standard benchmark for world-class operations that are replicable, transferable and adaptable across industries. For distributed computing, Gartner uses six categories: change management, operations management, asset administration, customer service, training, and technology planning and process management.

Best practices address how widely a task is performed, how often it is performed, how it is performed (manually or automatically, scheduled or ad hoc) and what tools are necessary to do it well. They are used in the TCO tool to simulate a particular environment.

The indirect cost of end-user operations is the single largest identifiable cost in the TCO studies, and the direct cost of operations is not far behind. By implementing best practices, IT managers can reduce these costs. Windows software provides tools to simplify user and computer management and provides administrative flexibility. Some of the key areas where Windows software enables IT departments to implement best practices and thereby reduce operations cost are: standards compliance, hardware and software deployment, change management technology, data management, and performance monitoring.

The impact of Windows software tools on the government enterprise's ability to implement these five best practices for managing and monitoring their IT operations are shown in Exhibit 15.

Exhibit 15: Impact of Windows Software Tools to Implement Best Practices

Metric	Improvement with Windows over Linux	Savings per PC	Savings per Server
Standards compliance	102%	$17	$847
Deployments	57%	$27	$1,391
Change management process	50%	$21	$1,082
Data management	75%	$14	$699
Performance monitoring	57%	$6	$307

Appendix A, "Best Practices—Feature, Function, and Savings" provides additional details about each best practice, quantifies their impact and explains how Microsoft technology was able to generate the results.

Impact of Geography

Because 80 percent of TCO represents labor costs, organizations in countries with lower labor costs should expect that TCO in their locality is less of a factor in selecting an operating system.

As labor becomes cheaper, the ratio of hardware to software in the TCO equation becomes higher. At roughly $5 per hour, the fully burdened cost of an operating system becomes relevant, and Windows becomes more costly.

In the TCO studies conducted in Europe, North America, Asia and South America, labor was indeed cheaper than in the United States. (See Exhibit 16.) When the TCO was recalculated using actual salaries, burden rates, and hours per staff year, the results still favored the Windows upgrade over the Linux solution.

In North America, the average TCO for the Linux solution was 13 percent higher than for the Windows upgrade. In Europe the average TCO for the Linux solution was 17 percent higher than for the Windows upgrade. In Asia and South America, the average TCO for the Linux solution was 7 percent higher for the Linux solution than for the Windows upgrade. (See Exhibit 17.) The cost of labor never dipped so low that it yielded an advantage for Linux.

Exhibit 16: Average FTE Hourly Rate by Region

Region	Fully Burdened Hourly Rate	
	IT Employee	End User
North America	$42.14	$22.26
Europe	$27.59	$20.94
Asia	$15.25	$7.77
Worldwide	$31.76	$18.66

Exhibit 17: Windows TCO Advantage Normalized on Actual Data by Region
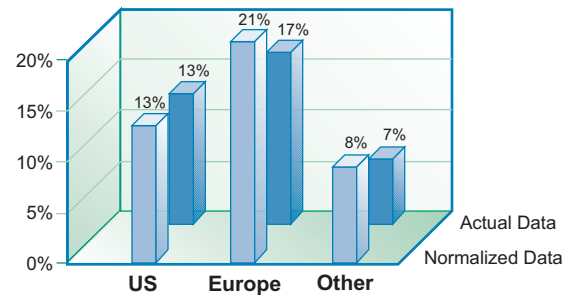
This chart displays the actual TCO data observed with normalized data. It was necessary to normalize the data to U.S. salaries in this paper so that results would come from the IT environment and management practices rather than from FTE salary rates. Surprisingly, in the low-cost labor markets, Windows had a better TCO, even though the lower FTE rates reduced the advantage.

Impact of Changing Platforms

Moving from one platform to another can be costly. The cost results from the TCO for the IT infrastructure and the cost of migrating the applications from one platform to another. The average TCO per desktop for the Windows upgrade is $3,693, whereas the average TCO per desktop for the Linux migration is $4,210. (See Exhibit 18.) However, the TCO of the infrastructure is not the only cost. Additional costs that arose during the studies are discussed below.

At the moment, there are very few tools to help organizations migrate from Windows systems to Linux. These tools may or may not be created in the future, but they do not exist now. In the 16 TCO studies, this gave Windows a significant advantage since it was the incumbent platform. Also, because of the larger installed base for Windows, organizations have more options available for applications and peripherals. For the customers studied, more options translated to lower cost.

Exhibit 18: Average Migration Cost from Windows 9x and Windows NT 4.0 to a New Platform

	Average Migration Cost	
	Windows	Linux
Cost per Desktop (includes server)	$3,693	$4,210

Any time a platform is changed, there are significant transfer costs. Since most of the organizations studied were primarily running on Windows, this worked in Microsoft's favor.

Windows or Linux? Evaluate the Total Cost of Ownership Before You Decide

The following examples illustrate the hidden costs that were uncovered during this phase of the TCO studies.

The cost of porting custom software created for and supported by the Windows environment to the Linux environment. One company had a small custom database that ran on nearly every Windows desktop, and many users had customized it further for their specific job needs. This could not be easily ported to Linux. To migrate the database from the current Windows version to Linux was estimated to be a huge effort going forward, more than three times the total yearly IT staffing budget—85 man-years of effort.

Incompatibility between desktop applications. Most companies have a large number of existing documents in Microsoft Office format. While StarOffice and OpenOffice generate documents that are said to be compatible with Microsoft Office documents, in reality there are small differences. For example:

- Font usage may be incompatible between the various Office suites.

- Existing Microsoft macros will not execute in StarOffice or OpenOffice.

- Documents that are password protected in Microsoft Office applications cannot be opened at all in StarOffice or OpenOffice.

- The user interfaces of these two suites are different, so users will require time and training to learn the new interface.

In the studies in which StarOffice or OpenOffice was part of the solution, this translated to additional migration and on-going support costs (since the organizations will continue to receive incompatible documents externally).

Using a migration cost spreadsheet provided by Gartner, it was determined that the average StarOffice or OpenOffice migration would cost the organization $2,391 per user and an additional $1,700 per year per user in end-user operations costs due to lost productivity. These studies only considered the cost of migration when using the Microsoft Office Standard Edition.

If Microsoft Office Professional Edition is considered, then migration from Microsoft Access would also have to be considered, adding significantly more cost.

The cost of developing specialty device drivers in Point-of-Sale (POS) applications. The TCO model used in these studies does not include POS devices such as cash registers and card scanners. However, one of the participating retail companies was concerned that if it moved to a Linux environment, it would have difficulty finding software to support older equipment of this kind. This company actually looked into the availability of such device drivers, and indeed they were not available. The risk of having to develop and support custom software or having to buy new equipment was considerable, and in this particular case, a showstopper. The other retail companies did not address this issue in their studies. However the area is significant enough to warrant further studies.

The cost of developing interfaces to database applications that exist for Microsoft Office and interfaces for Office-like applications that run over Linux. Many database applications systems interface to Microsoft Office applications, especially Microsoft Word and the Microsoft Outlook® e-mail client. These applications do not necessarily interface as easily to other productivity products, such as StarOffice or OpenOffice. In one company, the primary use of the IT infrastructure was to access large centralized database systems, some with this type of interface.

In addition to the organization-specific data above, the following trends were also encountered across the 16 studies.

The costs of additional system testing that could be incurred by using software tools for Linux, which are developed by a number of different suppliers. Many small companies are now developing stand-alone software tools for Linux which provide functionality similar to that contained in Windows software. The hidden costs in using these tools is reflected in the need to ensure interoperability between them and the added complexity in the IT environment caused by having multiple vendors and software packages to support.

In addition, no single supplier ensures that a Linux-based system has passed a comprehensive set of regression tests for security fixes or extra functionality. Since Linux is driven by the user community, software is not developed through a common source and is not necessarily subjected to comprehensive regression testing by a single company. This forces additional costs of testing on to the user and adds the risk of software incompatibilities and additional system downtime. This was seen as a serious risk by several of the companies studied.

The cost of additional software for administrative and management functions. In combining Linux with existing systems, it might be necessary to create some custom scripts or to purchase third-party packages to support all the system management functions desired.

Third-party packages range from freeware to expensive management tools. In three of the studies the cost of these third-party packages was included in the implementation costs for the Linux migration, which actually made the software license more costly than the software license costs for the Windows upgrade. If scripts are necessary, once they have been created, the cost of maintaining them will be incurred going forward. These scripts could also make upgrades or switching back to a Windows environment more expensive.

These costs were outside the scope of the TCO studies, and some of them were not modeled extensively in any of the studies. However, they are mentioned here because in a number of studies, they were considered important enough by the companies to eliminate Linux as a contender. For other companies, they represent areas that needed further investigation of the costs and risks that could be incurred by implementing a Linux solution.

Conclusions

Although the Linux operating system itself is considered cost-free, software is only one component of an increasingly complex enterprise computing infrastructure, which includes server and storage hardware as well as many kinds of application software. Although Linux is perceived to be free, research from a TCO perspective consistently confirms that when all the ancillary costs, such as application integration, ongoing infrastructure management, and support are added, the aggregate total cost of ownership is greater than Windows.

When considering either upgrading or converting your main system software, it is essential to consider the ongoing or recurring costs in addition to one-time, up-front costs. As demonstrated by these studies, the costs of supporting IT and end-user operations are the overwhelming portion of the cost over the lifecycle of the system. To try to minimize those costs, select software that:

- **Reduces the complexity in hardware and software configurations.** By implementing uniform configurations across your company, the number of different items that your technical support personnel must handle is reduced. Additionally, the time it takes to fix them is reduced.

- **Enables you to implement those best practices that will have the biggest effect on lowering costs.** Many of these practices are procedures for administration of your systems.

- **Allows you to provide adequate training and support** for your staff and end users.

The results of these studies indicate strongly that Microsoft Windows is a more economical choice over the lifecycle of an operating system.

Windows offers a complete software solution. It reduces the complexity of your software. It has integrated tools that facilitate the implementation of best practices throughout your organization. And because it is so widely used, there are certification programs that ensure that your staff is adequately trained.

Because Linux support costs often are higher than Windows, Linux does not reduce application infrastructure TCO. When TCO and ROI are considered, Windows is generally the least expensive option.

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Appendix A: Best Practices—Feature, Function and Savings

Standards Compliance

One critical aspect of reducing the cost of operational management (and the TCO) is to ensure that all clients conform to a standard configuration. The difference between doing this badly and doing it well is very important. Even small changes can significantly affect the TCO. The group of TCO studies performed at government enterprises is the benchmark of this section.

Exhibit 19: Average TCO Improves with Use of Best Practices

Standards Compliance	
Industry	Government
Improvement with Windows	102%
Savings per PC	$17
Savings per Server	$847
Enabling Windows Features	Active Directory and Group Policies

Because the Active Directory directory service and Group Policies can be used to assign and enforce standard configurations on users and machines, Windows scored significantly higher than Linux, particularly in the government group, where the metric was on average 60 percent better than for Linux. Exhibit 19 shows the correlation between the savings per server and the value of the best practice metrics for standards compliance.

In another case study, the ability to do this was seen as a deal breaker because the company already used Windows and controlled its desktop configurations very well. The IT department wanted the ability to lock down the end-user desktop configuration and didn't want to introduce the complexity and lack of control inherent in a Linux system.

Deployment

Windows software offers a number of tools for managing hardware and software deployment. (See Exhibit 20.) These tools include:

Exhibit 20: Average TCO Improves with Use of Deployment Best Practices

Deployment	
Industry	Government
Improvement with Windows	57%
Savings per PC	$27
Savings per Server	$1,391
Enabling Windows Features	Remote Installation Services IntelliMirror technology User State Migration tool

- Remote Installation Services (RIS), which automates operating system installations.

- IntelliMirror management technologies, which automatically restore user states.

- User State Migration, which helps users to migrate personal data and settings from an old system to a target system during an operating system upgrade.

Change Management

Change management addresses the activities that are planned, scheduled and performed on a regular, proactive basis. It includes the technical support for installs, moves, adds, changes and removals of networks, systems, and system components.

Change management technology and processes have a significant impact on the TCO. In any of the case studies where central control of the user application is critical, this is a vital best practice for containing cost. Windows IntelliMirror

software installation enables just-in-time installation, self-healing application, and full rollback after failure. (See Exhibit 21.)

Data Management

Data Management involves backup, restore and repository services for client and server data. Microsoft Windows software provides automated data synchronization between clients and servers with automated server progressive backup and allows for the automated recovery of user data after a disaster.

System Preparation utilities can image new PCs, and IntelliMirror and Group Policies restore user applications, state information and data. (See Exhibit 22.)

Performance Monitoring

Performance monitoring and event management are processes and activities that enable support personnel to detect problems in early stages and to prevent problems from happening. Performance monitoring is possible using the Performance Monitor utility included in Microsoft Windows Server™ software.

Additionally, Windows has an API which makes it possible for other software packages to be integrated into the system to provide more performance monitoring features including proactive repair and maintenance. Some examples of such programs include: NetIQ, CA Unicenter, BMC Patrol, Tivoli and Microsoft Operations Manager. These products are not available for Linux because they lack the necessary APIs. (See Exhibit 23.)

Exhibit 21: Average TCO Improves with Use of Change Management Best Practices

Change Management	
Industry	Government
Improvement with Windows	50%
Savings per PC	$21
Savings per Server	$1,082
Enabling Windows Features	IntelliMirror technology Self-healing application Full rollback after failure

Exhibit 22: Average TCO Improves with Use of Data Management Best Practices

Data Management	
Industry	Government
Improvement with Windows	755%
Savings per PC	$14
Savings per Server	$599
Enabling Windows Features	Automated data synchronization User data recovery System Preparation utilities Group Policies

Exhibit 23: Average TCO Improves with Use of Performance Monitoring Best Practices

Performance Monitoring	
Industry	Government
Improvement with Windows	57%
Savings per PC	$6
Savings per Server	$307
Enabling Windows Features	Performance Monitor utility
Other Products that run on Windows	Microsoft Operations Manager Microsoft Application Center NetIQ

Appendix B: Results by Industry Type

The organizations studied in this report can be divided into four industry groupings: government, retail, banking, and a final group that included a manufacturing firm, an insurance company, an outsourced services company and a communications firm. Results of the Windows-Linux TCO comparison are shown in Exhibit 24.

Reviewing the TCO results by industry type produced the following observations.

Government

Typically, the government studies involved both clients and servers supporting a large number of applications. Windows benefited in these circumstances because of its adherence to standards, support for change management and operations management. The need for document conversion and peer support were also key factors supporting Windows in these studies.

Exhibit 24: TCO Result Comparison by Industry

Windows average TCO cost savings percentage better than Linux, normalized and actual data. Because the industry data was skewed by regional salary levels, industry data was normalized on U.S. salaries. This chart compares the normalized and non-normalized data.
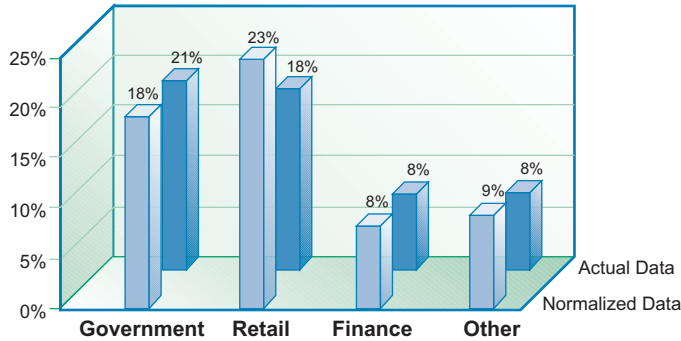
- Two of the participants saw a TCO advantage for Windows of 12 percent over Linux.

- In two other studies, the clients ran Windows applications from a Windows Terminal Server. The Linux solution required the purchase of expensive third-party, Citrix client-server software that enables Linux clients to run Windows applications from Windows Terminal Server. Tivoli-based Linux solutions also required software to manage client PCs. The additional cost of these software packages yielded a TCO for Windows of 20 percent less than Linux.

- In the fifth case, the cost of end-user operations in the Linux solution was a major factor contributing to a 27-percent TCO advantage for Windows.

The TCO savings in government was $699 per desktop for Windows when compared to Linux.

Retail

The biggest factor in the TCO studies in the retail segment was in the cost of supporting the operations. Typical retailers have centralized application servers that support a variety of input and output devices at their retail locations. They also have a number of industry-specific peripherals that are supported now by Windows drivers that would have to be rewritten in a Linux environment. Although not specifically included in the TCO calculation, this factor became a deal breaker for some of the companies studied.

The studies were split into two groups.

- In one group operations costs were 15 to 30 percent higher for Linux than Windows, and the resulting TCO was 6 to 8 percent lower for Windows.

- In the other studies, the operation costs were 60 to 70 percent higher for a Linux environment, and the calculated TCO for Windows was 30 to 40 percent less than for Linux. This was a result of much higher costs for the Linux solution in areas of application management and hardware deployments. However in the case of one company, the salary levels and overhead burden were significantly lower than in the normalized case.

The TCO savings in the retail sector was $139 per desktop for Windows when compared to Linux.

Finance

The key factor in the financial sector had to do with the cost of supporting end-user applications. Since the end users were not at all familiar with Linux, the costs attributed to peer support and casual learning was very high. In fact, the percentage of indirect costs (end-user operations and the impact of downtime) was higher for these case studies than the average, driven in part by higher manpower requirements for Linux. Also, the average salary of financial end users was significantly higher than the other industries studied. This had a dramatic impact on the cost of end user operations.

In all of these situations, the cost of hardware was slightly favorable to Linux, but that advantage was outweighed by higher costs in IT and end-user operations.

The TCO cost advantage for Windows in this group ranged from 2 to 13 percent.

The TCO savings in the financial sector was $399 per desktop for Windows when compared to Linux.

Other Industries

This category includes manufacturing, outsourcing services and communications companies, most of which supported a large number of servers and desktops. In three of the four scenarios, the driving factor for Windows was the ability to remotely manage and maintain a large number of desktops—as many as 15,000 in one company. The indirect costs, end-user operations and downtime, were very high, more than 51 percent of the TCO.

TCO savings ranged from 4 to 19 percent.

The TCO savings in this group was $340 per desktop for Windows when compared to Linux.