Synopsis

BSc. (Hons) Business Information Systems

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"An Investigation into the Analysis, Design and Implementation of a Server Consolidation project employing Virtualisation Software."

This report concentrates on the investigation of virtualisation software as a viable means of Server Consolidation. The analysis focuses on the capabilities and testing of virtualisation and attempts to document how virtualisation is applied within a large organisation.

Acknowledgements

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Project Overview

1.1 Introduction

As Powergen has expanded its need for IT, the installation of new servers has happened in an almost constant stream. Since the price of an Intel based server is relatively low, the purchase decision has been made at the business unit level rather than requiring corporate approval. Whilst this approach is effective for meeting the immediate requirement for the IT systems, this approach has its drawbacks: Less than optimal use of server resources; high maintenance costs; increased datacenter environment costs including space, power and cooling; and higher staffing levels. All these reasons ultimately lead to low quality of service to Powergen's end users.

Datacenter space within Powergen has reached such critical levels that they can no longer sustain the deployment rate of new servers, a fact that will soon begin to hinder Powergen's capability to service the IT needs of the business units. Powergen has recognised these symptoms and are investigating ways of reducing costs whilst bettering levels of service to the end users. Server Consolidation offers a way to gain control over server numbers by increasing the utilisation of resources and reducing the complexity and costs of maintaining and managing them.

1.2 Aims of the Project

This dissertation will demonstrate the various solutions, along with Powergen's framework for successful delivery and implementation of Server Virtualisation. The scope of study will be to evaluate the piloting phase of the Server Consolidation project from virtualisation testing to rollout within the Web Operations team.

1.3 Objectives of the Project

In order to fulfil the aims of the dissertation the following points will be addressed:

1. Investigate the current project management practices at Powergen.
2. Discuss the testing and implementation of VMware used by Powergen.
3. Analyse the capabilities and opportunities for deployment of virtualisation.
4. Draw conclusions and recommendations for future research.

1.4 Structure of Report

Chapter Two – Literature Review

This section will provide background information on Powergen and demonstrate the reasoning behind virtualisation being considered a viable solution for Server Consolidation. The relative benefits of virtualisation will then be explored alongside the methods of implementation.

Chapter Three – Methodology

The methodology by which this study was undertaken will be publicised within chapter three. All elements of qualitative research and quantitative research will be defined and presented here.

Chapter Four – Results

This section presents the results from the qualitative and quantitative analysis undertaken in chapter three and provides an investigation and summary, including examining the validity of data.

Chapter Five – Discussion

The section discusses the potential limitations of the study. A discussion on the questionnaire results and semi-structured interview results will provide the basis for further conclusions and recommendations.

Chapter Six – Final Conclusions and Recommendations

These findings from chapter 5 will be related to theory outlined in chapter two. The implications of the research findings for Powergen, and organisations in general will be highlighted. Recommendations for further research will be suggested and closing comments made.

Chapter Two

Literature Review

2.1 Company Background

Powergen UK is a subsidiary of the E.ON group, the world's largest investor-owned utility company, responsible for generating, distributing and retailing gas and electricity to a UK customer base of around 9 million. E.ON employs around 67,000 people in countries including: Germany, Finland, Sweden, Switzerland, Italy, Holland, Hungary, Czech Republic, Slovakia, Latvia, Lithuania, Russia, Poland, the United Kingdom and the United States.

In the industrial and commercial (I&C) market, E.ON has pan-European gas and power expertise, owning I&C Retail businesses and supplying industry and commerce in countries including Germany, Sweden, Poland and Finland.

(Powergen Intranet, 2004 [online])

2.2 Company Structure

Powergen/E.ON UK is made up of the following business units;

Asian Asset Management is responsible for completing the divestment of E.ON UK's remaining investments in overseas IPP projects in Indonesia, Pakistan and Turkey.

Central Networks, the distribution business combining Midlands Electricity and East Midlands Electricity, is responsible for delivering a supply to 4.8 million customers in central England.

Energy Wholesale manages and develops the company's generation and related assets across coal, oil, gas, CHP and Renewable technologies

E.ON Energy is the brand name under which electricity and gas is sold to large industrial and commercial business customers. Since the liberalisation of the industrial and commercial market in 1989 E.ON Energy has been the leading supplier of electricity to British industry and a major gas supplier.

The following supporting divisions assist UK businesses achieve their strategy;
The UK Centre is made up of four key business units: UK Finance, UK IT, UK HR and UK Legal. These work closely with each of the four UK businesses to provide the skills and competencies they require in support of their business objectives.
E.ON UK's Services business was set up to deliver high value and cost effective services to the UK business through standardised processes and e-technology. It continues to look to identify additional opportunities where common processes can be developed and where appropriate resources can be shared.

2.3 Company Vision

E.ON's objective is to be the world's largest integrated power and gas company. The strengthening of its market position in Europe and the sustainable increase of the group's performance are core to E.ON's strategy.

E.ON's five target markets are Central Europe, pan-European gas, UK, Nordic and US Midwest, within which it has leading positions in generation, trading, distribution and supply (Powergen Intranet, 2004[online]).

2.4 Powergen's IT Strategy Shift

The Server Rationalisation project, of which Server Virtualisation is a division, forms part of a high-level, IS strategy in the direction of a 'Federal IT model' achieved by systems consolidation. The Federal model "gains the best levels of performance and efficiency from platform infrastructure at the best possible cost, while maintaining responsiveness and alignment with business unit characteristics." ('Strategic Direction (1)', Powergen Internal Communications, 2003)

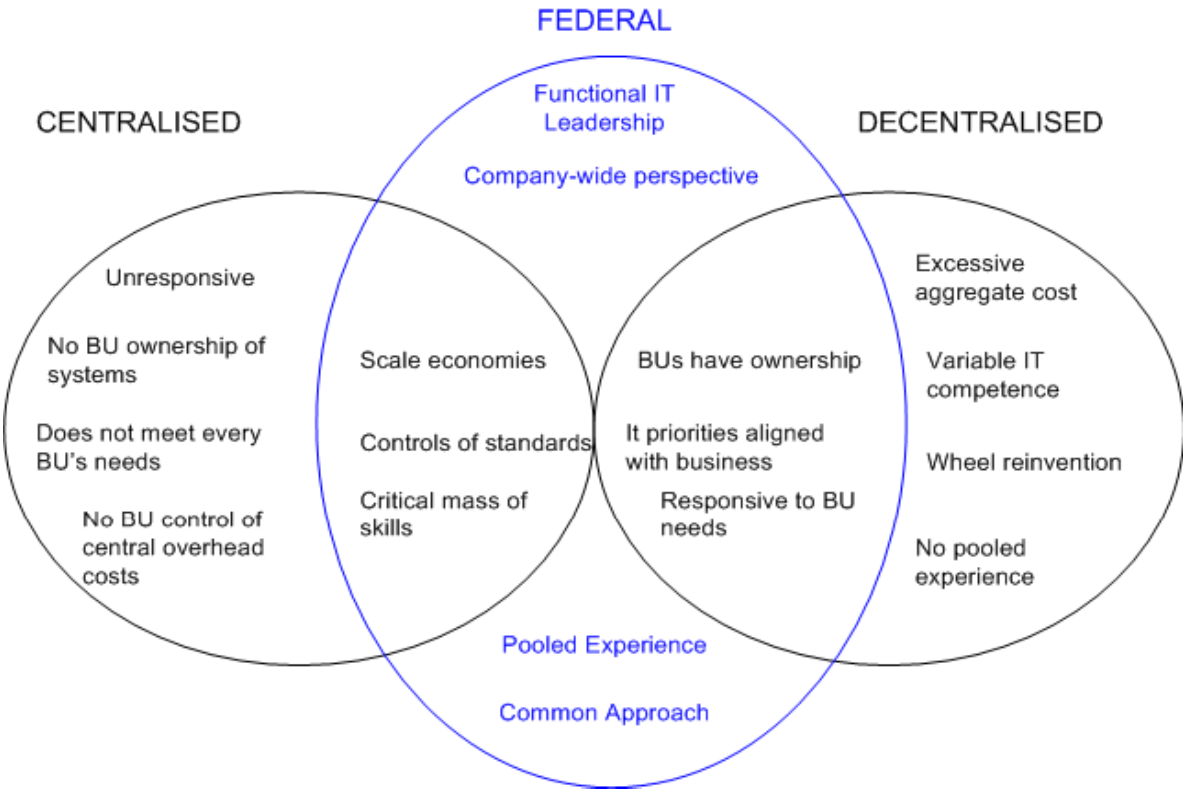

Figure I – Powergen's Federal Model

One of the outcomes of realising the Federal model is an environment whereby "IT infrastructure treats distributed resources as part of a virtual system" ('Strategic Direction (2)', Powergen Internal Communications, 2003).

This form of 'utility computing'[1] provides value in areas of reduced costs driven by efficient resource usage, improved service levels accomplished by tuning of IT services and increased agility by "rapid provisioning of new services or resources and scaling of established services." ('Strategic Direction (2)', Powergen Internal Communications, 2003). In essence, the short term benefits of the model are based upon improved resources and management efficiencies whereas long term adoption to the model, as transcribed within the Powergen Internal Communications (2003), will

[1] "*Utility computing* treats a data center's compute, storage, and networking components as shared resources. The data center may belong to the business or may act as an infrastructure provider to otherwise independent businesses" (Machiraju et al (2002), Quality Of Business Driven and Utility Computing, p7)

facilitate transition to new technologies and sustain competitiveness with industry best practice, eliminating the need for major change or outsourcing program(s).

However, in order to sustain this approach to supporting Information Systems, it is necessary for the correct infrastructure to first be in place. It was believed that "enterprises that have at least partially consolidated their IT environments will be well-placed to rapidly adopt workload management and server virtualisation that arrive with policy-based computing.[2]" ('Server Consolidation (1)', Powergen Internal Communications, 2003). That is to say, that at the time of initiating the Server Consolidation project, some business units were already in a position to adopt server virtualisation as a means of consolidating servers. Powergen have adopted a series of high-level collaborative approaches with the emphasis on pooling resources initially within the Operations teams and ensuring progress targets are continually monitored. This can be viewed in Appendix 1, "Powergen Internal Communications, Platform Strategic Direction: Agreed Approach."

2.5 Problem Definition

As part of the short-term action outlined above, a reduction in the number of servers is a major driver for change. Before the Server Consolidation project, the status of servers/platforms within Powergen was as follows:

- Powergen employed around 640 servers, including over 200 NT4 Servers. This has arisen from the 'one server per application' paradigm, a standard practice for around 6 years which has also caused an increase in the number of locally attached tape drives and consequently, tens of thousands of tape changes per annum.

[2] Sahai et all, (2004), defines policy-based computing as "ensuring correct behavior of a reasonably complex application through such rules", Sahai et all. (2004), Automated Policy-Based Resource Construction in Utility Computing Environments, p2

- An excessive number of distributed servers[3], which in turn carry significant support costs and complexity.
- Microsoft ceased support for Windows NT in December 2004; therefore any existing NT Servers would be 'out of support' unless moved to Windows Server 2000/2003.

This was a direct result of the 'one application per server paradigm' that had been adhered to previously, in an attempt to reduce compatibility issues with conflicting applications.

A decision was then made to evaluate Intel server environments for opportunities to consolidate distributed applications onto newer, larger platforms in the form of The Server Rationalisation Project ('Server Consolidation (1)', Powergen Internal Communications A, 2003).

Nine high level objectives were highlighted in the project mandate as follows:

1. Reduce overall operational costs through the reduction of physical servers, having the following effect:
    i. Reduction in number of licences.
    ii. Reduction in overhead on DC facilities (heat, power)
    iii. Reduction in support man-hours
    iv. Reduction in actual server and storage hardware (reduced maintenance etc.)
2. Completely eliminate the presence of Windows NT4 server from E.ON server estate by end of 2004 to avoid being 'out of support' in 2005.
3. Create a Windows 2003-based Intel server and storage architecture and service that is used as a standard approach for all new deployments, moving away from the 'one server, one application' approach. Reduce number of different

[3] Large networks have multiple servers. Servers are often distributed around the network with a server on every subnet, which improves booting efficiency, but conflicts with the goals of central configuration control. The more servers, the more dispersed the control, and the more likely that a configuration error will occur. (Hunt, C. (1997) *TCP/IP Network Administration*, O'Reilly, Ch.9)

server builds and system policies as part of architecture. Ensure that future server growth and provisioning is controlled through application of strict governance, capacity management, and asset management.

4. Produce a process that enables new application requirements to be matched to the most appropriate target architectures, including a robust capacity planning process.
5. Centralise servers into main data centre locations where possible.
6. Reduce level of direct attached storage.
7. Cause minimal disruption to the business throughout deployment.
8. Enable the support teams to adopt a more proactive approach to performance monitoring by reducing the volume of infrastructure.
9. Creation of platform services to deliver standard hosting environments for areas such as development/web/infrastructure/packaged application servers etc.

(Powergen Internal Communications, 2004)

The Server Rationalisation team proposed a mixture of the following solutions:-

- Simple Consolidation
  - Moving applications to an existing server
- Virtualisation
  - Installation and configuration of VMWare's Virtual Server to allow multiple operating system implementations on the same infrastructure
- Multiple Instance Integration
  - Databases apportioned to an application which can be moved easily and efficiently
- Do Nothing
  - Leave existing infrastructure/implementation in place

As part of the evaluation, a project feasibility study was undertaken to determine if server virtualisation really is a viable solution for reducing the number of physical

servers. A number of virtual server instances would be piloted within the Web Operations team to test resilience and co-existence after which the project success will be considered along with further rollout plans. The success of the project relied on the following key deliverables:

- Reduced Hardware Costs
- Reduced the number of Servers
- Reduced the number of Storage Devices
- Reduced the number of Devices to Backup and Backup Devices
- Reduced Software Costs
- Reduced the number of Operating Systems and versions of Operation Systems
- Reduced the number of Processor Licences
- Reduced the IT Support Costs
- Reduced overheads for Monitoring and Management of Servers
- Reduced Environment Costs
- Reduced required Datacenter Space
- Reduced required Power Consumption
- Ability to Implement solution
- Ability to be handed over into Operational Support

(Powergen Internal Communications, 2004)

Powergen's program of work for the Server Consolidation project can be found in Appendix 2.

2.6 Virtualisation

This section will attempt to demystify some of the terminology and benefits from utilizing server virtualisation and through discussion, provide an encompassing definition for the term 'virtualisation'.

2.6.1 Definition of Virtualisation

According to Goldberg (1974)[4], a 'virtual machine' (VM) is defined as, "an isolated duplicate of a real existing computer system, in which statistically-dominant subset of the virtual processor's instructions be executed on host processor in a native way".

Kim (2004)[5] states that virtual machines have been studied since the late 1960s and are experiencing a resurgence in commercial and research areas (Harris, 2001[6], King, 2002[7]). Both Operating System level virtual machines (Goldberg 1974, Creasy, 1981[8], Waldspurger, 2002a[9]) and virtual Operating Systems (Jiang, 2004[10]) allow multiple-guest operating systems to be hosted on the same hardware platform (Bugnion, 1997[11]).

Singh (2004 [online][12]) summarises virtualisation as something that "extracts out things" but goes on to provide a more comprehensive definition in his unpublished article 'An Introduction to Virtualization', whereby virtualisation is defined as:

> A framework or methodology of dividing the resources of a computer into multiple execution environments, by applying one or more concepts or technologies such as hardware and software partitioning, time-sharing, partial or complete machine simulation, emulation, quality of service, and many others.

[4] Goldberg, R (1974). Formal Requirements for Virtualizable Third Generation Architectures, *In Communications of the ACM*, vol 17, issue 7, pp 412-421
[5] Kim, D (2004). Flexible Virtual Machines in Distributed Systems and Grids, p 5
[6] Harris, T (2001) Extensible Virtual Machines, *PhD Thesis, Churchill College, University of Cambridge*
[7] King, S. (2002) Operating System Extensions to Support Host-Based Virtual Machines, *Technical Report, University of Michigan*
[8] Creasy, R. (1981) The Origin of the VM/370 Time-Sharing System, *IBM Journal of Research and Development, vol 25, issue 5, pp483-490*
[9] Waldspurger, C. (2002a) Memory Resource Management in VMware ESX Server, *Proc Of the 5th symposium on Operating systems design and implementation*, pp181-194
[10] Jiang, X, (2004) Protection Mechanisms for Application Service Hosting Platforms, *Proc Of IEEE/ACM Int'l Symposium on Cluster Computing and the Grid*
[11] Bugniuon, E. (1997) Disco: running commodity operating systems on scalable multiprocessors, *Proc Of the Sixteenth ACM Symposium on Operating System Principles, pp143-156*
[12] Singh, A (2005) An Introduction to Virtualization [online], Available at: http://www.kernelthread.com/publications/virtualization/ [Accessed 15th February 2005]

An extension of the term, *'Paravirtualization'*, was first coined by the developers of Xen, an alternative x86 virtual machine monitor which, in a similar fashion to VMware and more freely available virtual machine software, "allows multiple commodity operating systems to share conventional hardware in a safe and resource managed fashion, but without sacrificing either performance or functionality." (Barham et al, 2005b[13]). The distinguishing feature of Xen however, is that whereas previous applications use full virtualisation[14], Xen only provides an abstraction which is similar but not identical to the underlying computer. This approach, or paravirtualisation method, provides improved performance levels but requires modifications to the guest operating system (Barham et al, 2005a[15]).

The actual process of virtualisation is done courtesy of the Virtual Machine Monitor (VMM). Waldspurger (2002b,[16]), defines a VMM as a "software layer that virtualises hardware resources, exporting a virtual hardware interface that reflects the underlying machine architecture." Singh (2004 [online]) provides a more simplified explanation, "a layer of software that provides the illusion of a "real" machine to multiple instances of "virtual machines". The term originates from the original Virtual Machines developed in the late 1960's (Smith and Nair, 2003a)[17].

2.6.2 Virtualisation Vs Emulation

Although similar in terms of purpose and concept, there is a clear distinction between emulation and virtualisation. Virtualisation (as defined previously) is a technical term that refers to a mechanism for creating multiple contexts on a single processor. Whereas emulation is a "…process whereby one computer is set up to permit the execution of programs written for another computer. This is done with…hardware features …and software…" (Lichstein, 1969[18]). The main advantage of emulation is

[13] Barham et al (2003) Xen and the Art of Virtualisation, p164
[14] Whereby the virtual hardware exposed is functionally identical to the machine on which it sits.
[15] Barham et al (2003) Xen and the Art of Virtualisation, p165
[16] Waldspurger, C. (2002b) Memory Resource Management in VMware ESX Server, *Proc Of the 5th symposium on Operating systems design and implementation*, pp181
[17] J.Smith, J. and Nair, R (2003a), An Overview of Virtual Machine Architectures, *Virtual Machines: Architectures, Implementations and Applications*, p5
[18] Lichstein, H. (1969) When should you emulate?, *Datamation*, pp205-210

that a processor can be emulated on any other type of processor. The main disadvantage is that it tends to be slow.

In the context of software, an emulator reproduces the behaviour of one system on another. It executes, or strives to execute, the same programs as the 'original' system, and produces the same results for the same input. It is important that the user of an emulator is not supposed to care how (Singh, 2004). Similarly, in the context of computing, a simulation is an imitation of some real system.

For further information on emulation, Efrem Mallach, (1994) has done extensive work on the shared characteristics of Virtual Machines and Emulators in his paper, 'On the Relationship Between Virtual Machines And Emulators'.

2.6.3 The Need for Server Virtualisation

Smith and Nair, (2003b)[19] ascribes the need for virtualisation to the limitations –or interoperability- imposed by the 'major components'[20]. They suggest that there are three major problems with computer systems; software compatibility (primarily thorough different operating systems), the need to support legacy systems and the constraints placed upon users to use a matching operating system and hardware platform (which may provide opportunities for exploiting security holes).

Within the context of this report, the need for server virtualisation is one of reduced cost, rather than limitations of hardware. Molta (2004[online]),[21] declares that one of the biggest management challenges faced by IT organizations today is the proliferation of servers. Powergen, like many organizations, have a separate server, or even multiple servers for each application. While consolidation is a worthy goal and has potential to greatly reduce administrative costs, Molta (2004[online]), claims that

[19] J.Smith, J. and Nair, R (2003b), 'An Overview of Virtual Machine Architectures', *Virtual Machines: Architectures, Implementations and Applications*, p7
[20] Smith and Nair define the major components as "the hardware, the operating system and the application programs." (p2)
[21] Molta, (2004 [online]), Available at: http://web.syr.edu/~djmolta/ist753/servers.htm [Last Accessed 10th March 2005]

such a strategy is difficult to implement in a client/server environment. He states that the primary reasons for this are a lack of scalability of many operating systems and the lack of system software that allows managers to dedicate resources to specific applications. This is also magnified by the trend towards decentralization of services in many organizations. Departments and business units implement their own servers because they want to optimize their IT environment to meet their unique needs rather than settling for generic services offered by an often over-burdened IT organization. These departments and business units face their own pressure to consolidate but the same technical issues that confront central IT often manifest at the departmental level. (Molta, 2004[online]).

Waldspurger (2002c[22]), suggests that recent industry trends such as server consolidation and the proliferation of shared-memory of multiprocessors have fuelled a "resurgence of interest in server virtualisation techniques". In many computing environments, as in the case of Powergen's infrastructure, individual servers are underutilised, allowing them to be consolidated as virtual machines on a single physical server. Similarly, many small servers can be consolidated onto fewer larger machines to simplify management and reduce costs.

Madden (2004 [online])[23] reports that the rise in server virtualisation and specifically VMware can be largely attributed to a flaw in the Microsoft Windows kernel[24]. The case emerged during Spring 2002, that when building large Citrix Servers or Terminal Servers, the maximum number of users per server was always in the range of 200-225, regardless of the amount of memory or processing power. The cause of which was later found to be that the server can only use around 2GB of memory, regardless of the physical amount of memory installed within. This would result in user limits being reached when around 200 sessions were running on a single server.

[22] Waldspurger, C. (2002c) Memory Resource Management in VMware ESX Server, *Proc Of the 5th symposium on Operating systems design and implementation*, pp181

[23] Madden, B (2004 [online]), Citrix And VMWare Past, Present & Future, Available at: http://www.brianmadden.com/content/content.asp?id=51, [Last Accessed: 5th March 2005]

[24] The kernel is the program that constitutes the central core of a computer operating system and has complete control over everything that occurs in the system.

The problem was escalated further when hardware manufacturers such as IBM had already began manufacturing servers capable of scaling up to 16 processors (x440 Servers), but with limitations caused by the operating system, were completely ineffectual in the Citrix and Terminal Server based infrastructures as dual processor hardware was only supported.

Therefore organisations looked to VMware to provide a solution. By allowing multiple images of Windows servers to run together on the same physical server, it became possible to run 8 or 16 virtual Citrix servers, providing support for 1000 to 2000 Citrix users (or sessions) on the one x440 server.

(Madden, 2004 [online])

2.6.4 VMware

VMware is a product that allows multiple 'virtual servers' to be run on one physical server. As the diagram below shows, several instances of various operating systems can be loaded on one physical system. Each instance is an unaltered retail or enterprise copy of the selected OS and runs entirely exclusive of the other instances.

The VMware 'virtual' layer redirects I/O from the Operating system instances, or virtual servers, to and from the real hardware. The configuration and management of VMware is performed by a Web based console interface (the Virtual Center) that runs independently of the hosted operating systems.

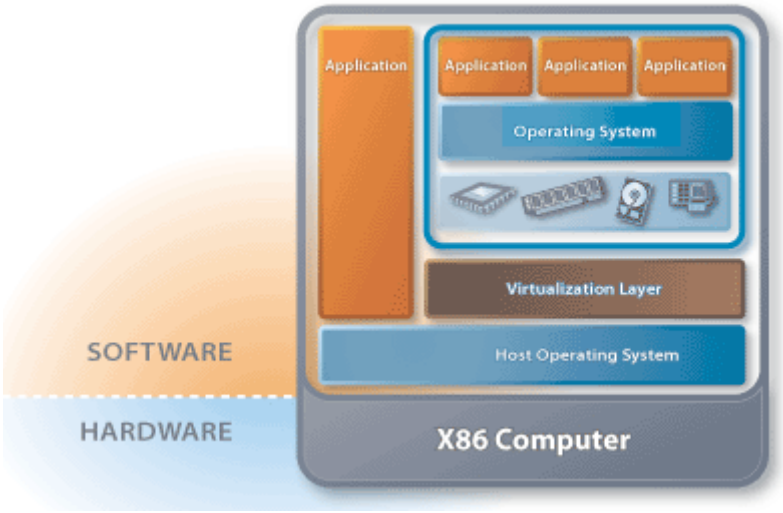

Figure II: The VMware System Layout

2.6.5 VMware ESX Server

VMware ESX Server is a thin software layer designed to multiplex hardware resources efficiently among virtual machines. The current system virtualises the Intel IA-32 architecture, in use on servers running multiple instances of unmodified operating systems. VMware ESX Server is designed for large-scale production server environments, supporting with up to 16 processors. (Waldspurger, 2002[25])

[25] Waldspurger, C. (2002) Memory Resource Management in VMware ESX Server, *Proc Of the 5th symposium on Operating systems design and implementation*, pp181

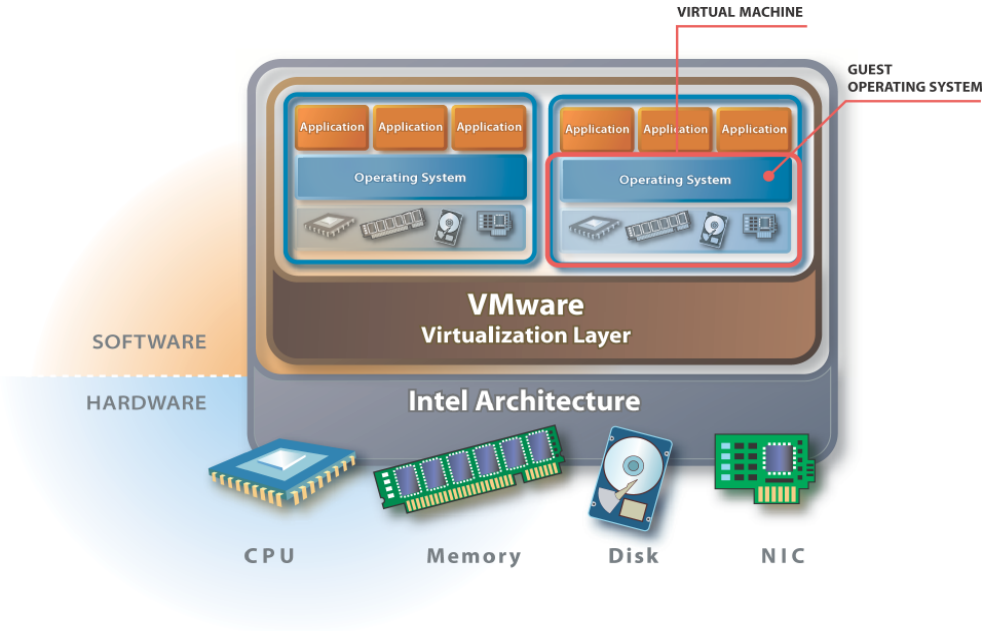

Figure III: VMware ESX Server System Layout

The basic premise of VMWare is discussed in Barham et al's (2005) journal, 'Xen and the Art of Virtualisation', commenting that the ESX Server:

> …dynamically rewrites portions of the hosted machine code to insert traps wherever VMM intervention might be required. This translation is applied to the entire guest OS kernel (with associated translation, execution, and caching costs) since all non-trapping privileged instructions must be caught and handled. ESX Server implements shadow versions of system structures such as page tables and maintains consistency with the virtual tables by trapping every update attempt.

For further information of a more technical nature on the techniques which VMware employs, see 'Memory Resource Management in VMware ESX Server' by Carl Waldspurger (2002).

2.6.6 Virtualisation Selection Process

The decision to opt for VMware as the technical solution for virtualisation was based on the reality that the virtual server market only had two main companies and

products in the Windows Intel Market that were scalable for an organisation the size of Powergen. These are Connectix Virtual Server and VMware GSX / ESX server. However since Microsoft have acquired Connectix this product is unavailable[26]. (Powergen Internal Communications, 2004)

The following flow diagram was constructed in order to determine which of the three Server Rationalisation solutions would be most appropriate:

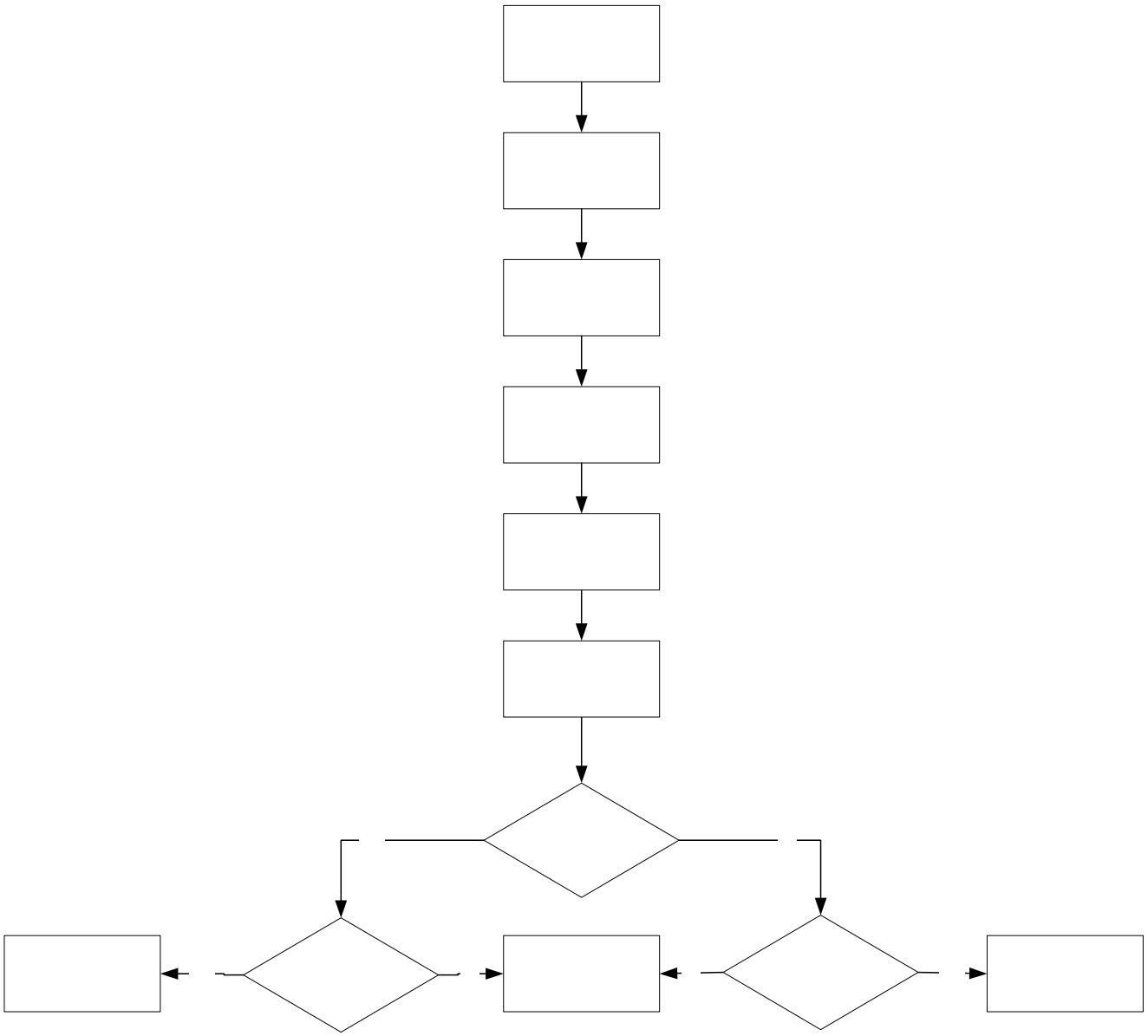

Figure IV: Solution Selection Process

[26] Microsoft have recently relaunched the Connectix product under the name Microsoft Virtual Server 2005, but does not provide support for Linux operating system.

A flow chart of the process of implementing virtualisation is shown below:

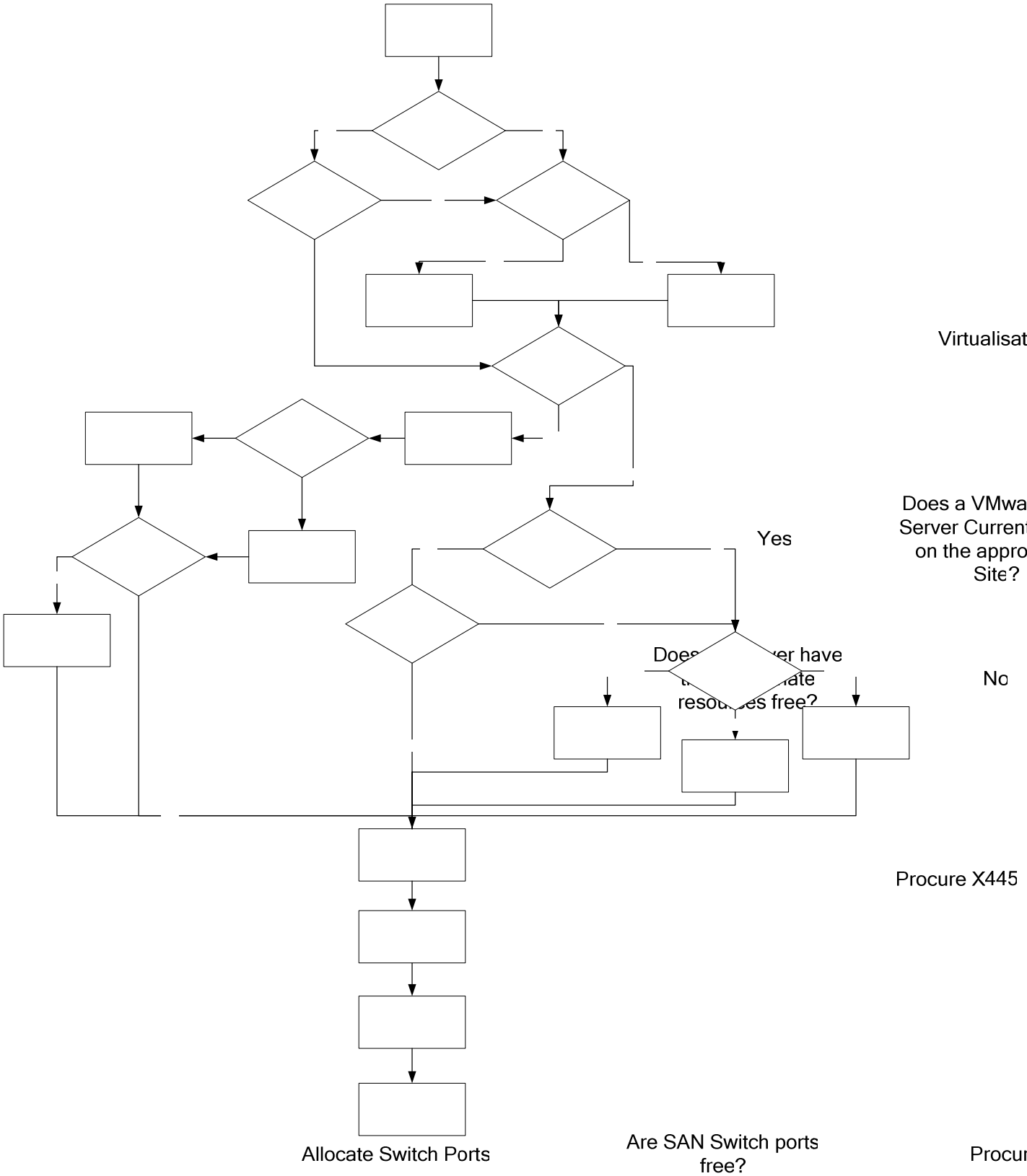

Figure V: Virtualisation Selection Process

2.7 Project Management

This section aims to discuss the concept of Information Systems Development Methodologies. It will illustrate the approach Powergen took to manage and implement the VMware system and provide the platform on which to discuss the stages of the methodology and their relevance to the Server Consolidation environment.

2.7.1 What is a methodology?

Avision (1995[27], p.10) defines an information systems development methodology as:
"A collection of procedures, techniques, tools and documentation aids which will help the systems developers in their efforts to implement a new information system."
Avison (1995) then goes on to state how a methodology should consist of "phases", which themselves consist of sub-phases to "guide the systems developer in their choice of techniques that might be appropriate at each stage of the project." Avison 1995 concludes the argument by explaining how these techniques support the system developer to "plan, manage, control and evaluate information systems projects."

2.7.2 Why a methodology is required

An appropriate methodology is essential in any systems development because it provides a systematic method of development allowing progress to be monitored (Bocij et al (1999a[28]). The use of well-defined stages in a methodology enables effective tracking of the system development and facilitates requirement specification on the part of the users as well as allowing the systems developers to investigate and analyse the requirements. (Bocij et al, 1999a)

[27] Avison, D and Fitzgerald, E.(1995) *Information Systems Development, Methodologies, Techniques and Tools*, London, McGraw-Hill, p10
[28] Bocij et al (1999a) *Business Information Systems*, Essex, Prentice Hall, p246

2.7.3 Powergen's Methodology

Powergen's internal project methodology has been adopted from processes in both PRINCE2[29] and ISO9001 ITSU procedures.

The methodology consists of a series of five phases, these are:

1. Project Startup
2. Project Initiation
3. Project Development
4. Project Implementation
5. Project Closure

For a more detailed view on the actions involved within each phase, refer to Appendix 3, UKServices Project Management Procedures.

Similarly to PRINCE2, the Powergen project management approach is constructed around a process-based approach to project management. The processes clearly define the management activities to be carried out during the life of the project. The ideology of this method of management can be explained by Bentley (2002a[30]) who declares how having the outcomes clearly defined at the outset allows "the project to remain focused on achieving business results, whatever the current activity".

2.8 System Changeover Strategies

This section will also provide an evaluation of implementation strategies, as a basis for comparison, outlining the elected approach taken by Powergen.

Changeover can be defined as "moving from the old information system to the new information system." (Bocij et al, 1999b[31]). When considering the alternatives, the main factors of concern are; cost, time, quality of new system after changeover, impact on customers, impact on employees and technical issues.

[29] Prince2 is a structured project management approach which provides a set of best practice processes and is widely used within both the public and private sectors for the effective management of projects (Office of Government Commerce, 2002)
[30] Bentley C. (2002) Prince 2: A Practical Handbook, 2nd Edition, Butterworth Heinemen, p36
[31] Bocij et al (1999b) Business Information Systems, Essex, Prentice Hall, p470

There are four main alternatives for moving from a previous system to a new system. These are:

- Immediate cutover or 'big bang'
- Parallel
- Phased
- Pilot

Bocij et al (1999c[32]) provides a comprehensive review of each of the alternatives, for the purposes of this report, they have been summarised in the following diagram:

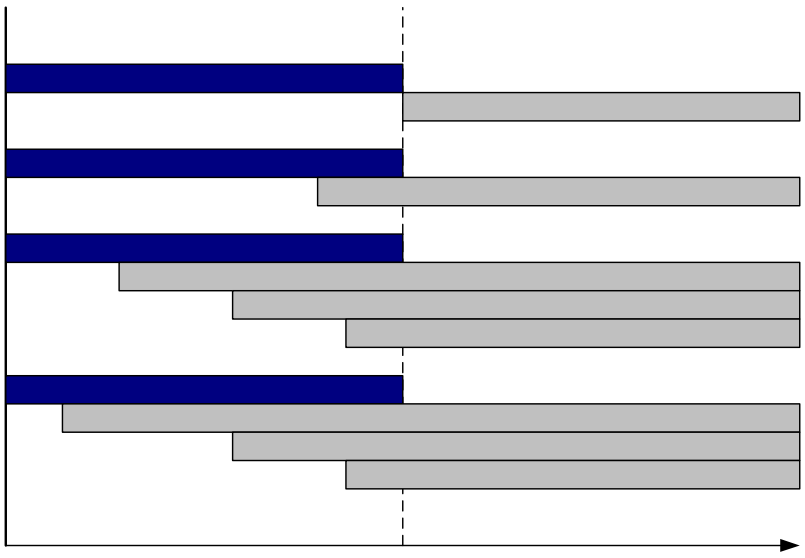

Figure VI: Alternative changeover methods for implementation

In order to implement server virtualisation, Powergen will employ a combination of changeover strategies for different stages of implementation. From a high-level perspective, virtualisation as a means of server consolidation will initially be implemented within a single Business Unit and phased through to additional Business Units depending upon the success of each subsequent implementation. However, from an Operational standpoint, the Web Operations team will be the target of the first pilot

[32] Bocij et al (1999c) Business Information Systems, Essex, Prentice Hall, p471

scheme in the UK Services Business Unit. As part of the pilot scheme, virtual servers will run alongside physical servers in parallel until co-existence of virtual and existing architecture is assessed as performing adequately. This presents a lower risk than the immediate cutover method, since if the new system fails, the Consolidation team can revert to the old system and the Web Operations team will not be greatly affected. Although Bocij exclaims that "The cost of running the two systems in parallel is greater than any other form of implementation, not only in terms of maintaining two sets of software and effectively hardware, but also in the costs of the human operators repeating operations." the argument is not applicable in this scenario as the cost of running virtual servers is negligible in comparison to their physical counterparts. In addition, both physical and virtual servers will be manned by the same personnel

Chapter Three

Methodology

3.1 Introduction

The purpose of the research chapter is to investigate the objectives laid out in section 1.3 of this report.

3.2 Research Strategy

Research strategy is a way to carry out an inquiry system into a phenomenon being studied by showing the approach that is used in order to gather data and analyse. (Saunders et al, 2002a)[33]

Robson (1993[34]) lists the three traditional research strategies as:

- Experiment
- Survey
- Case study

The experimental research strategy has been disregarded on the grounds of unsuitability to the scope of this thesis. This strategy is largely conducted for social sciences (Saunders et al, 2002b[35]) with the researcher having a greater level of involvement than afforded within this study. A survey approach would provide greater control over the research process; however, Saunders et al (2002c)[36] argue that analysis of questionnaires generated by this strategy is time consuming to such an extent that it may hinder progress –especially when depending on others for information.

[33] Saunders et al (2002a), *Research Methods For Business Students*, Prentice-Hall, p74
[34] Robson, C. *Real World Research: A Research For Social Scientists and Practitioners and Researchers*, Oxford, Blackwell, p47
[35] Saunders et al (2002b), *Research Methods For Business Students*, Prentice-Hall, p75
[36] Saunders et al (2002c), *Research Methods For Business Students*, Prentice-Hall, p76

The research project will therefore take a cross-sectional[37] perspective in the form of a case study, which is defined by Jankowicz (1991[38]) and Feigenbaum (1991[39]) as when the thesis, "focuses on a set of issues in a single communication, and you want to identify the factors involved" (p.163). In order to achieve this, a combination of both quantitative and qualitative forms of primary research will be undertaken. Primary data is defined as "data gathered and assembled specifically for the project at hand." (Zikmund 2002a[40]) whereas secondary data, or historical data, is "previously collected for some project other than the one at hand." Using this definition, the literature review in chapter 2 will be secondary research for this project, which includes information that is collected previously and documented by academics around the research subject area.

Zikmund (2002b[41]), states that primary data is invaluable as it is, "gathered and assembled specifically for the project at hand". Secondary data may be outdated or may not exactly meet the needs of the researcher because they were collected for another purpose." Zikmund (2002). This will result in research that is consistent with the objectives as outlined in section 1.3

Figure VII, summarises the steps covered in the research investigation;

[37] "A snapshot of phenomenon, taken at a particular time." (Saunders et al, 1997, p77)
[38] Jankowicz, A (1991) *Business Research Projects For Students*, London, Chapman & Hall
[39] Feigenbaum, A (1991) *Total Quality Control*, McGraw Hill, p163
[40] Zikmund, W (2002) *Business Research Methods 6th Edition*, The Dryden Press, Dryden, p52
[41] Zikmund, W (2002) *Business Research Methods 6th Edition*, The Dryden Press, Dryden, p53

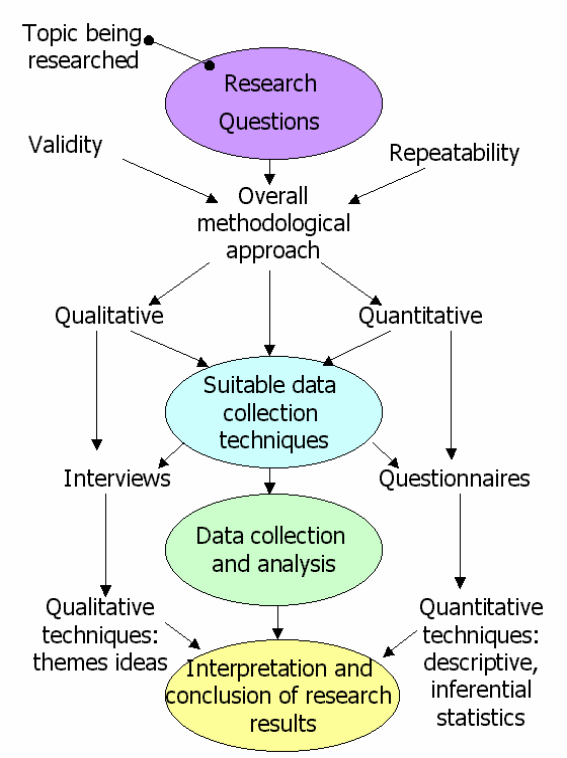

Figure VII: Steps in Research Investigation

3.3 Exploratory Research

Exploratory research is defined by Zikmund (2002[42]) as research with a clearly defined problem to aid in the definition of the problem and serve as a clarifying tool, identifying every potential issue surrounding the problem. The three interrelated purposes for exploratory research are: 1) diagnosing a situation, 2) screening alternatives, and, 3) discovering new ideas. (p103). For the purposes of this study, it was necessary for the author to gain a greater understanding on the subject of virtualisation before commencing any further research involving the Powergen Server Consolidation team. Therefore secondary information was gathered from internet sites, journals and printed material of which formed the literature review in chapter 2.

[42] Zikmund, W (2002) *Business research Methods 6th Edition*, The Dryden Press, Dryden, p55

3.4 Quantitative Research

Eldabi et al (2002[43]) state quantitative research methods rely on the measurement and analysis of statistical data, which is then used to determine possible relationships between that set of data to another. The tactic employed is principally questionnaires.

3.4.1 Questionnaires

The questionnaire was used to identify the response set of the Web Operations team to the new VMWare system. The aim was to identify the success rate of the implementation and obtain feedback for improvements. The questionnaire used a combination of fixed-alternative and open questions in order to gain the response set from the Web Operations team and provide feedback for future suggestion and discussion, respectively.

Dillman (1978[44]) categorises data that can be collected through questionnaires into four distinct types of variables:

- Attitudes (How respondents feel about the new system)
- Beliefs (What respondents think or believe is true or false)
- Behaviour (What respondents do/concrete experience)
- Attributes (Respondents' possessed characteristics)

The questionnaire will attempt to probe all the above variables, facilitating possible explanatory[45] study.

3.4.2 Questionnaire Planning

In order to plan the questionnaire, it is first necessary to clarify the questionnaire's aim: 'To obtain the attitudes (awareness, opinion and suggestions for improvement) of the Web Operations team towards the VMware server virtualisation software.'

[43] Eldabi, T. et al. (2002) Quantitative and Qualitative Decision Making Methods in Simulation Modelling. Management Decision, Vol.40 (1), p64
[44] Dillman, D (1978), Mail And Telephone Surveys The Total Design Method in Saunders et al (2002), *Research Methods For Business Students*, Prentice-Hall,, p250)
[45] Explanatory studies "establish causal relationships between variables." (Saunders et al, 1997, p79)

The next stage was to formulate the questions whilst ensuring they are both concise and unambiguous because although the target audience in this instance are all skilled computer technicians, a good questionnaire should phrase all questions simplistically, to reduce uncertainty. The questionnaire was afforded some degree of longevity as DeVaus cited by Saunders et al, p265 (2002d[46]) states that "optimal length will depend upon on your population, your research questions(s) and your objectives…The more specialised the population and the more relevant the topic, the longer your questionnaire can be."

3.4.3 Questionnaire Layout

The questions then had to be identified into open or fixed-alternative/closed questions. Open questions were limited in number and used largely as a means of allowing the respondent to provide feedback. Appropriate responses to the closed questions were one of the six types of closed questions identified by Youngman (1986);

- List – where the respondent is offered a list of items, any of which may be selected;
- Category – where only one response can be selected from a given set of categories;
- Ranking – where the respondent is asked to place something in order;
- Scale – in which a scaling device is used to record responses;
- Quantity – to which the response is a number giving the amount;
- Grid – where responses to two or more questions can be recorded using the same matrix.

Of the six types Youngman identifies, scale was used to gain an understanding of the respondent's attitude, and categorical responses provided factual answers targeted at analysing Project Methods.

[46] Saunders et al (2002d), *Research Methods For Business Students*, Prentice-Hall, p75

3.4.4 Pilot Questionnaire

A key failing of quantitative research is identified by Gable (1994[47]) when he states that survey instruments must pose the correct questions in the correct way. To overcome this potential pitfall, a pilot test[48] of a questionnaire was conducted using a small sample of operations staff in order to generate primary data. This was beneficial as it enabled the questionnaire to be refined with some assessment of the questions' validity. Preliminary analysis of pilot test data ensured that the data collected by the final questionnaire was of value.

Both content validity, as identified by Mitchell in (2001[49]), and face validity, explored by Saunders et al (2002e[50]), can then be firmly assured. Content and face validity ensure that the questionnaire is structured appropriately and makes sense to the recipient. A key outcome of the pilot questionnaire was that open ended questions could, with a selection of answers from the pilot test, be transformed into fixed alternative questions. A copy of the pilot questionnaire can be found in Appendix 4

The pilot questionnaire sample size used a convenience sampling approach[51] which involved piloting the questionnaire to two available members of the Web Operations team. The outcome of which resulted in largely grammatical and structural changes to the questionnaire.

3.4.5 Questionnaire Population

The final draft of the questionnaire covered a survey population of 24 members of Web Operations team using a questionnaire document in digital format delivered via email with a covering letter included within the body of the email (this can be viewed in Appendix 5). The final draft questionnaire can be viewed in Appendix 6.

[47] Gable, G. (1994)*Integrating Case Study And Survey research Methods,* Eur j Info, Syst, p112-126
[48] "A pilot test is any small scale exploratory research project that uses sampling but does not apply rigorous sampling standards." (Saunders et al, 2002)
[49] Mitchell, M (2001) *Research Design Explained*, 4th Edition, Pacific Grove
[50] Saunders et al (2002e), *Research Methods For Business Students*, Prentice-Hall, p76
[51] Convenience sampling designates samples selected strictly in terms of the opportunities available to the researcher advance.(Thietart et al (1999) Doing management research, p181)

3.5 Qualitative Research

Qualitative research is described by Eldabi et al (2002[52]) as, "distilled meaning and understanding phenomenon". As such, qualitative research methods are often associated with physical contact with individuals in the research setting, as well as with recording verbal data. Cavaye (1996[53]) identifies a significant flaw of qualitative research in that qualitative research is difficult and time consuming to analyse and analysis techniques are not well established. Therefore qualitative research will be used in a manner which provides an increased understanding on the nature of the project. Discussions will primarily be formed based upon findings from quantitative research.

3.5.1 Semi-Structured Interview

The tactics employed for qualitative research was by means of conducting a semi-structured interview[54] with the Server Consolidation Project Manager, with the aim of diagnosing the situation. The findings from the semi-structured interview were used to formulate the pilot questionnaire discussed in section 3.4.4, by identifying areas that should be questioned.

In order to plan for the interview, an agenda was formed to be used as a checklist to ensure that certain questions and areas were covered. The order of the questions also varied depending on the flow of the conversation. Additional questions were also used to explore the research questions and objectives.

Following Rudestan and Newton's (1992)[55] recommendation, the interview was tape recorded as this method offers low structure and low fidelity. After the interview, the recording was documented in a transcript.

[52] Eldabi, T. et al. (2002) Quantitative and Qualitative Decision Making Methods in Simulation Modelling. Management Decision, Vol.40 (1), p67
[53] Cavaye, A. (1996) *Case Study Research: A multifaceted approach for IS,* Information Systems, 1996, pp227-242
[54] Merton et al, 1990 explains that a semi-structured interview or 'focused' interview is one in which the interviewer defines a general subject area and uses a structured guide to allow the researcher to broach a series of subject areas in advance. (Thietart et al (1999) p181)
[55] Rudestan, K.E. and Newton, R.R, *Surviving your Dissertation*, Newbury Park, CA:Sage, 1992

3.5.2 Observation

Another form of collecting primary research data was taken from observation. Jorgensen (1989[56]) and Patton (2001[57]) both conclude that this can be in one of two forms[58] – internal viewpoint, whereby the researcher uses an approach based on participant observation or alternatively, external viewpoint – by conducting non-participant observation. Prior to VMWare rollout, a virtualisation testbed was established in which both an internal and external viewpoint was observed. The objective of this research was to try and establish the methodology used for testing.

To gain a better understanding of the methods used in resilience testing a number of sessions were arranged with the Server Consolidation team. These sessions initially involved the author viewing the operations from an external standpoint. Later sessions involved the author taking a more proactive role in the testing environment.

[56] Jorgensen, D (1989) Participant Observation: Methodology for Human Studies, Newbury, Sage
[57] Patton, M (2001) Qualitative Research And Evaluation Methods, Sage
[58] Junker (1960) and Gold (1970) also define four possible intermediary research positions; the complete participant, the participant as observer, the observer as participant and the complete observer.(Cited in Thietart et al (1999) Doing management research, p183)

Chapter Four

Results

4.1 Introduction

This chapter will provide the results from research outlined in chapter three. For all three methods – semi-structured interview, observation and questionnaire, an investigation and summary of results will be produced in preparation for discussion in chapter five.

4.2 Semi-Structured Interview

The transcript for the interview with Project Manager Julie Windridge can be found in Appendix 7. The initial aim of the interview was to provide background information on the processes of initiating a new project within Powergen and this was accomplished with Julie explaining many of the procedural management issues surrounding the project.

The interview may be also form the basis for further analysis. From the semi-structured interview it is apparent that there is a formal methodology which is adhered to. Results from the questionnaire which identify specific weaknesses or problems, reflect on areas which may be improved in the Powergen methodology.

Overall the interview identified the Project Manager's view on the progress of the Server Consolidation project and gave a good insight in to how the current status of the project should be.

4.3 Questionnaire Results

The results for the Web Operations questionnaire can be viewed in Appendix 8. The survey population, as mentioned previously was 24 members of the Web Operations team. Of these, the response rate was 18 replies.

4.3.1 Results Summary

None of the respondents chose to provide feedback on any of the 'open' questions in the survey (questions 4, 9, 14 and 15).

The response to question 1 shows a dramatic split in the awareness of the project, an indication that visibility of the project is low and even those who will be directly affected by the project were not informed until the day that virtualisation would be rolled out. The location of staff may also influence on these results. This will be explored in the results discussion in section 5.2

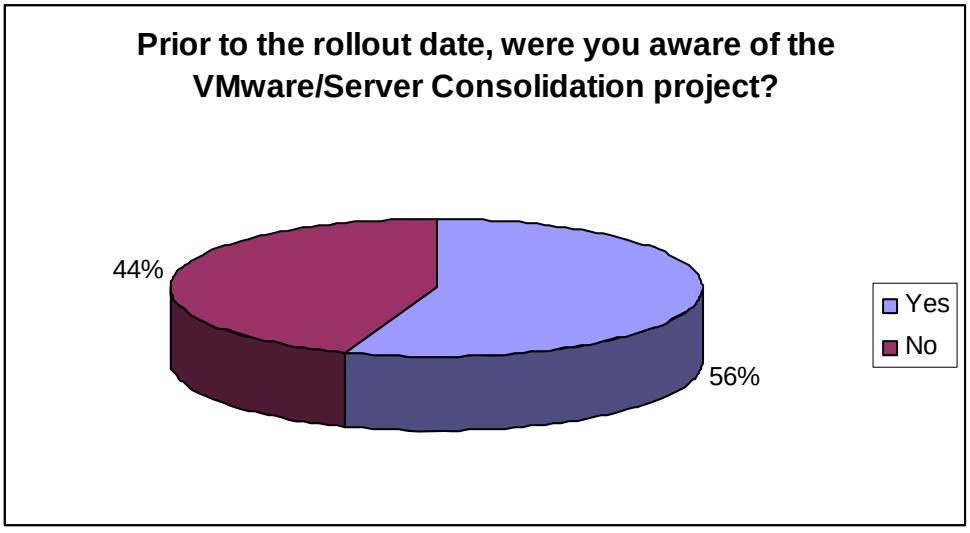

Figure VIII: Survey response to question 1

Of the 10 people who were aware, 80% had been informed of the project by word of mouth, showing a distinct lack of formal communication channels. Perhaps expectantly, indifference to any internal communications is the dominant response to question 3, with 44% of respondents, possibly due to the lack of formal communications identified in questions 1 and 2.

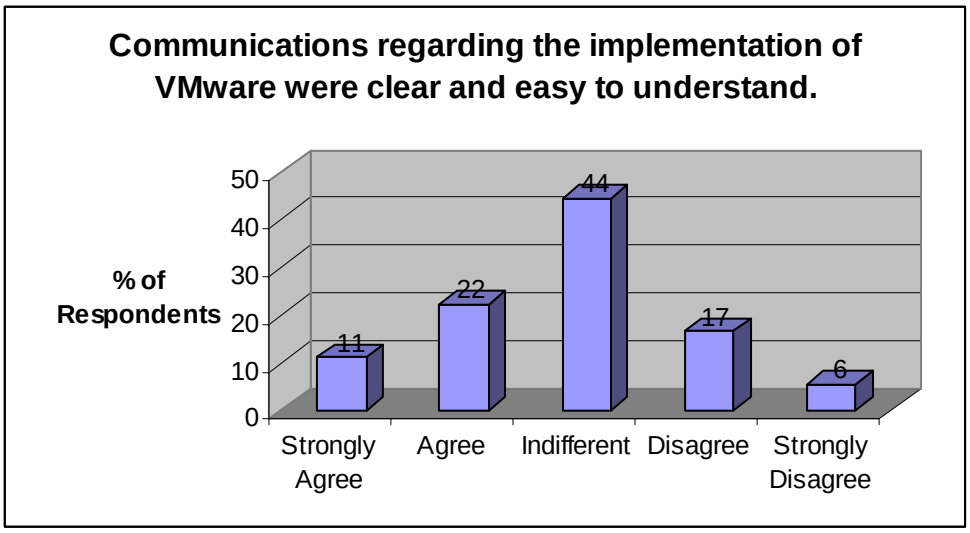

Figure IX: Survey response to 3

Once again a strong division indicates a split between the understanding for implementing VMware. 50% of the respondents within Web Operations have little or no understanding of the purpose of VMware after implementation whilst 39% believe they do understand why VMware is in use. This in direct correlation with question 6, whereby 39% believe they understand how VMware operates but interestingly, considering that at the time of the questionnaire VMware is already in operation, 54% do not know how to use VMware. The 11% of respondents who neither agree nor disagree with the statement may consider there knowledge of VMware sufficient enough to function the software but would not consider they 'fully' understand how the software works. Further clarification may be necessary in order to eliminate ambiguity for questions 5 and 6 in future research.

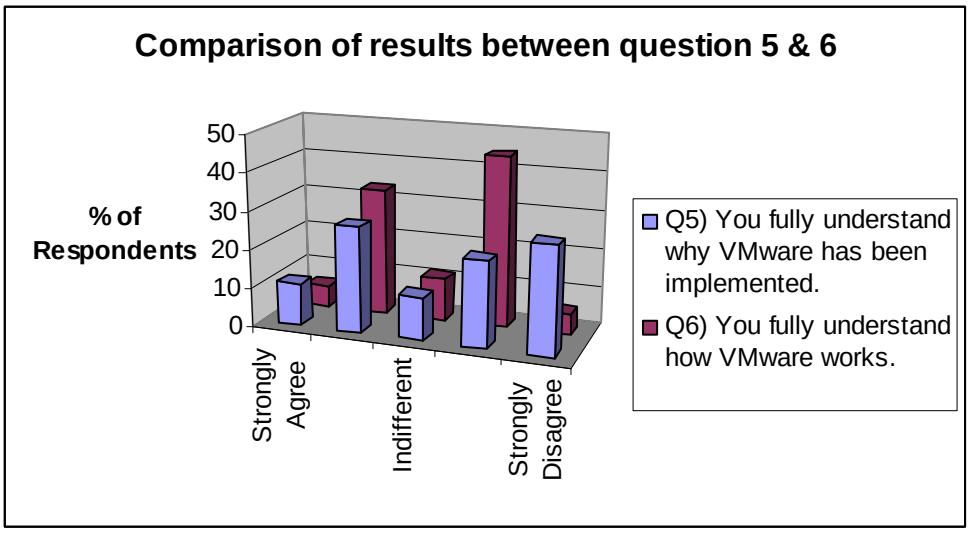

Figure X: Survey results to question 5 and 6

The need for training is reinforced in questions 7,8 and 10. 83% of those surveyed believed that a formal training session would be of benefit. Although quite a broad generalisation, the relationship between training and staff location is evident in the diagram below:

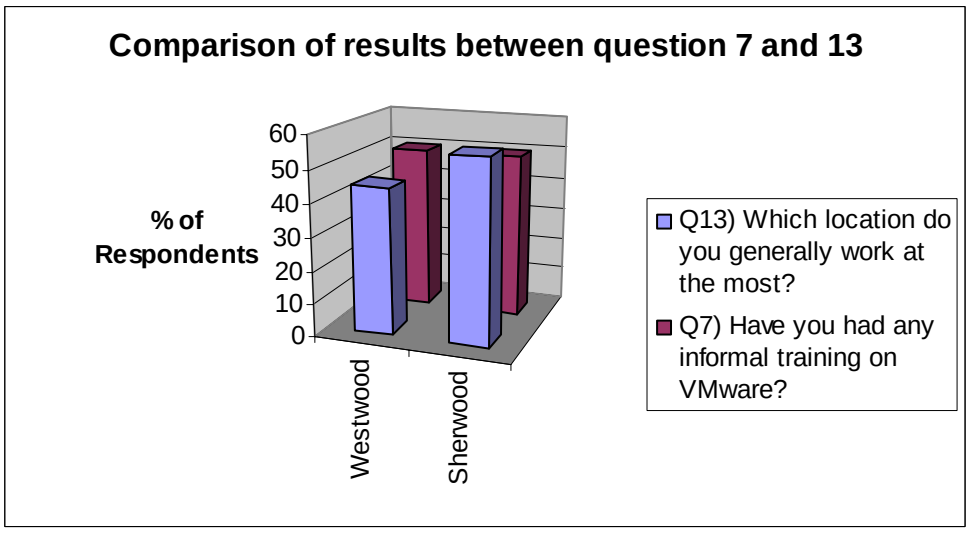

Figure XI: Survey results to question 7 and 13

Note that this does not show the location of staff who answered question 7, the X-axis should read 'Yes' and 'No' respectively as an available response to question 7.

Question 12, 'VMware adds further complication to an already complex support environment.' presented the chance to get a consensus of opinion on attitudes towards change. The 'split' evident in previous questions also holds true for question 12 which may draw interesting comparisons on perceived change and enthusiasm for new technology.

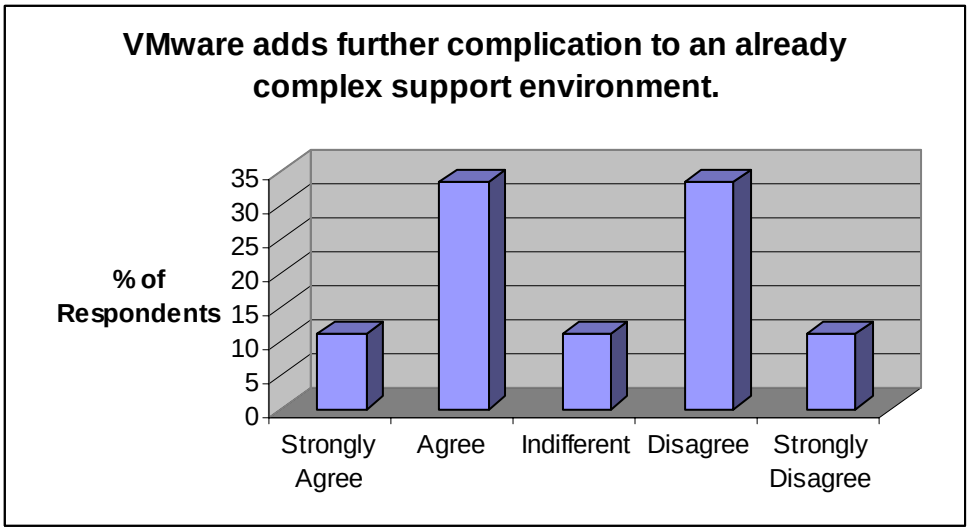

Figure XII: Survey results to question 12

The survey results highlight the need within the organisation for stakeholders of new systems to be made aware of change. Training is also an important factor which appears to have been overlooked; instead the Web Operations team are expected to train each other in an informal manner. The reasoning behind this practice will be discussed in chapter 5.

4.4 Observation

From the author's observations of the virtualisation testlab, a greater understanding of the process was realised. The areas tested were primarily concerned with resilience and co-existence with existing architecture to limit problems and conflicts after implementation. This was done via simulating the 'live' environment, tests and simulations on the interoperability between virtual machines as well as physical servers, application migration, and the operation of various applications such as Domain Controller, Exchange 2000 Server, SQL 2000, Web Server and IIS based

application servers. An overview of the recommendations and 'best practice' approaches, based upon results from the testbed are provided here:

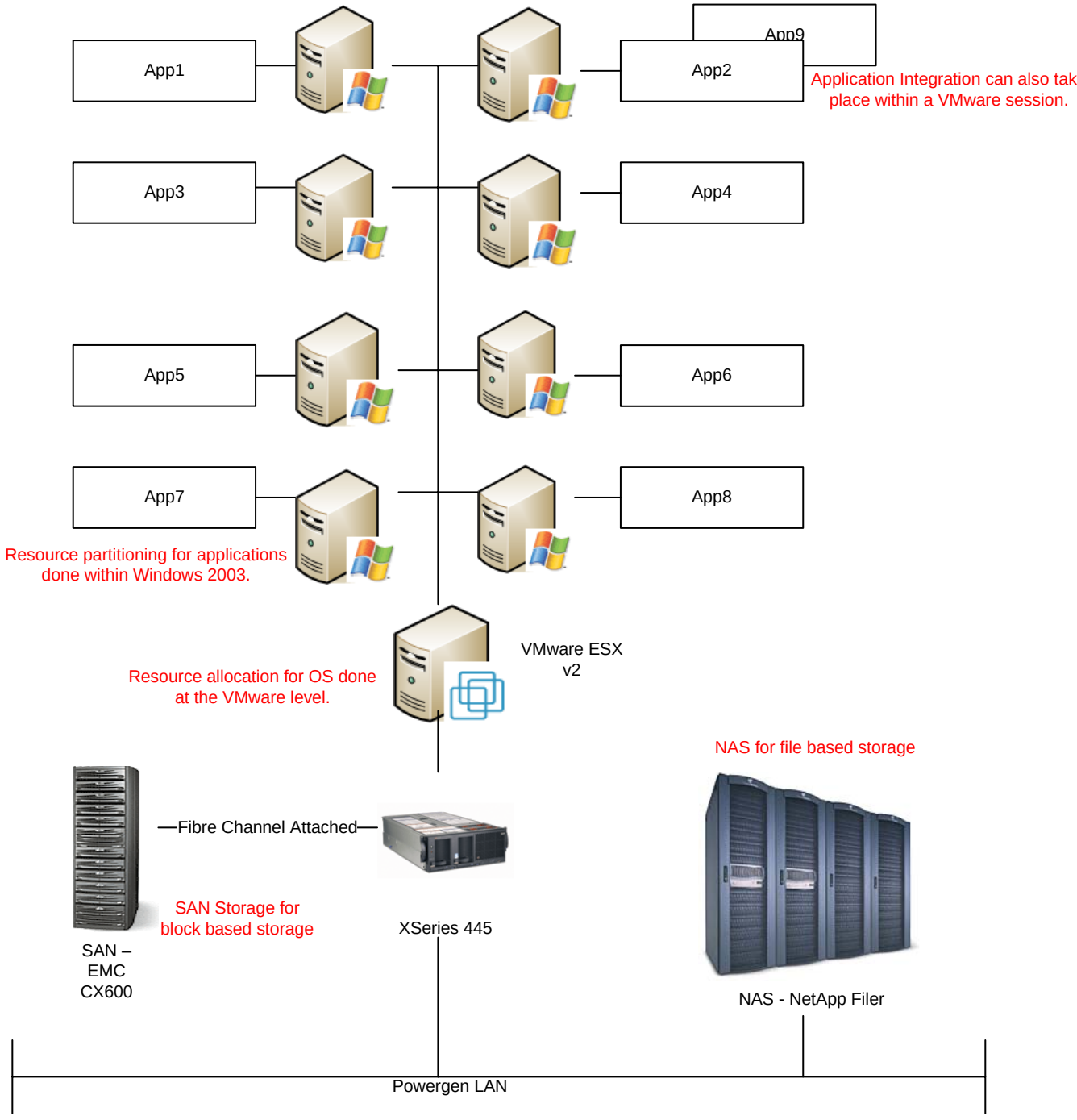

Figure XIII: System Topology

Note the network connections for both the server and the NAS storage should be Gigabit connections with no less than gigabit network between the two.
The number of Virtual machines displayed in the image above is not a direct representation of the amount possible

4.4.1 System Configuration

Each server must have a minimum of two network interface cards, although it is recommended that two Gigabit Ethernet adapters are teamed together, for every ten virtual machines that exist on a single server. Teaming will provide resilience for card failure and also switch failure as long as both NIC's are patched to different switches. Also for performance and security it is recommended that a separate 10/100 network interface card is supplied for the VMware Console. The IBM X445 has one Gigabit Ethernet adapter as standard so a number of dual port cards will be required to configure multiple virtual server instances.

IBM X445 (Or Retained IBM X440 or Compaq DL580-G2)	
Processors	4-Way 1.2GHz+ P3 Xeon Processors
Memory	4-8GB RAM
DAS	2 X 72 GB HDD RAID-1 for OS.
Supported OS	Host: VMware ESX v2. Guest: Windows 2000 Standard and Advanced Server, Windows 2003 Standard and Enterprise Server

Figure XIV: IBM X445 Specifications Table

Each server will be installed with VMware ESX Server v2 and then partitioned up according to the system requirements for each application. During the installation of ESX server the implementer must configure the three Linux disk partitions, one for the boot partition, one for the root partition and one for the console swap file. For this a direct attached SCSI disk is used.

During configuration of ESX a unique name will be needed and a required amount of memory for the VMware console. The below table details the amount of memory

required for the number of VM instances that are to be run. It also shows the size of swap file partition required in relation to the amount of memory used for the VMware console.

Number of Virtual Machines	Recommended RAM for VMware Console	Recommended Swap File Partition Size
1-4 VM's	128 MB	256 MB
5-8 VM's	196 MB	392 MB
9-16 VM's	272 MB	544 MB
17-32 VM's	384 MB	768 MB
>32 VM's	512 MB	1024 MB

Figure XV: Recommended RAM & Swap File for VMware

The initial instance build was done manually following the Windows 2000 or Window 2003 server build script and using Sysprep[59] to create a SID[60]-less operating system instance. Each subsequent build can be done by copying the initial instance .DSK file and configuring the new instance to use the copy of the initial .DSK[61] as its operating system. During configuration of the Virtual server the standard disk mode that Powergen should adopt is Append Mode[62] as this mode provides faster restores following server instance failures. After powering up the new instance the implementer would be prompted to enter the configuration details for the windows operating system.

Each server instance will be configured using the VMware web console and the appropriate amount of resources allocated to each instance. Once the base installation is complete it is advisable to install VMware Tools, which will allow high

[59] SysPrep is a SID generator that works with third-party disk-cloning tools such as Norton Ghost. SysPrep generates a unique SID and sets a few vital system parameters, such as the machine's NetBIOS name and the initial administrator account password.
[60] In Windows operating systems, the security identifier (SID) is a unique alphanumeric character string that identifies each operating system and each user in a network of NT/2000/2003 systems.
[61] The extended DSK image is a file designed to describe copy-protected floppy disk software. It's definition was defined by Marco Vieth, Ulrich Doewich and Kevin Thacker
[62] Append mode stores changes in a redo log. It continually adds changes to the redo log until the redo-log file is removed

performance graphics, time synchronisation, automatic cursor grab and release, copy and paste from between the management console and the instance, and improved network performance.

Each instance will also include additional applications including Symantec Antivirus, BMC patrol agents, IBM Director Agents, Patchlink client and the TSM backup client v5.2. A TSM client will also be installed on the VMware Console to backup the VMware .DSK files, application data and the VMware operating system.

On sites with SAN[63] attached storage available it is recommended that two fibre adapters are installed within each X445.

4.4.2 Storage Configuration

VMWare ESX systems partitions should be comprised of 2 X 72 GB Direct Attached SCSI Hard Disks, configured as RAID-1 (mirroring) to provide one logical 72 GB disk. By using RAID-1 across these two hard disks would provide fault tolerance for internal disk failure.

There are three partitions that must be created during install, namely boot, root and swap. Later during the configuration a VMware core dump partition will also need to be created on the direct attached storage. The remainder of the space on the DAS[64] disk can be configured as VMFS[65] and made accessible to only the virtual server instances on the server by setting the partition to private. This partition can be used for storing the VMware proprietary swap file for paging within VM's and must be at least the size of the physical memory in the server. Only four physical partitions can exit on a server so in order to create the Core Dump Partition and the additional

[63] Storage Area Network (SAN) is a high-speed subnetwork of shared storage devices.
[64] Direct Attached Storage: Storage hardware that connects to a single server.
[65] Most file systems, such as NTFS and EXT2, cannot have files larger than 2GB. This limitation means that with Microsoft Virtual Server and VMware GSX server the file that represents the virtual server's hard disks will have to be broken into 2GB segments. VMware ESX server overcomes this challenge by using a proprietary file system called VMFS. VMFS file systems do not have this limitation meaning that a 100GB virtual hard disk is a single file.

partition an extended partition must first be created through the VMware disk configuration screen.

Where VMware is to be used on SAN attached sites it is recommended that for performance the EMC Clarion CX600 storage devices are used for storage of the *.DSK and *.REDO files. This area is to be on raid 1 raid group dedicated to only one physical server, (One LUN[66]), and will not contain any application data. The size of this disk need to be a minimum of 4GB usable storage per virtual server instance, however this could fluctuate depending on the working requirements of the application to be hosted on the particular instance. The recommendation is to not have more that ten server instances hosted from the same RAID group. For more instances then it is possible to duplicate the above configuration.

[66] A term used in the context of devices connected to a SCSI controller. Each device on a SCSI controller has a SCSI ID, but each SCSI ID may have several LUNs that translate to several hard disks or removable media.

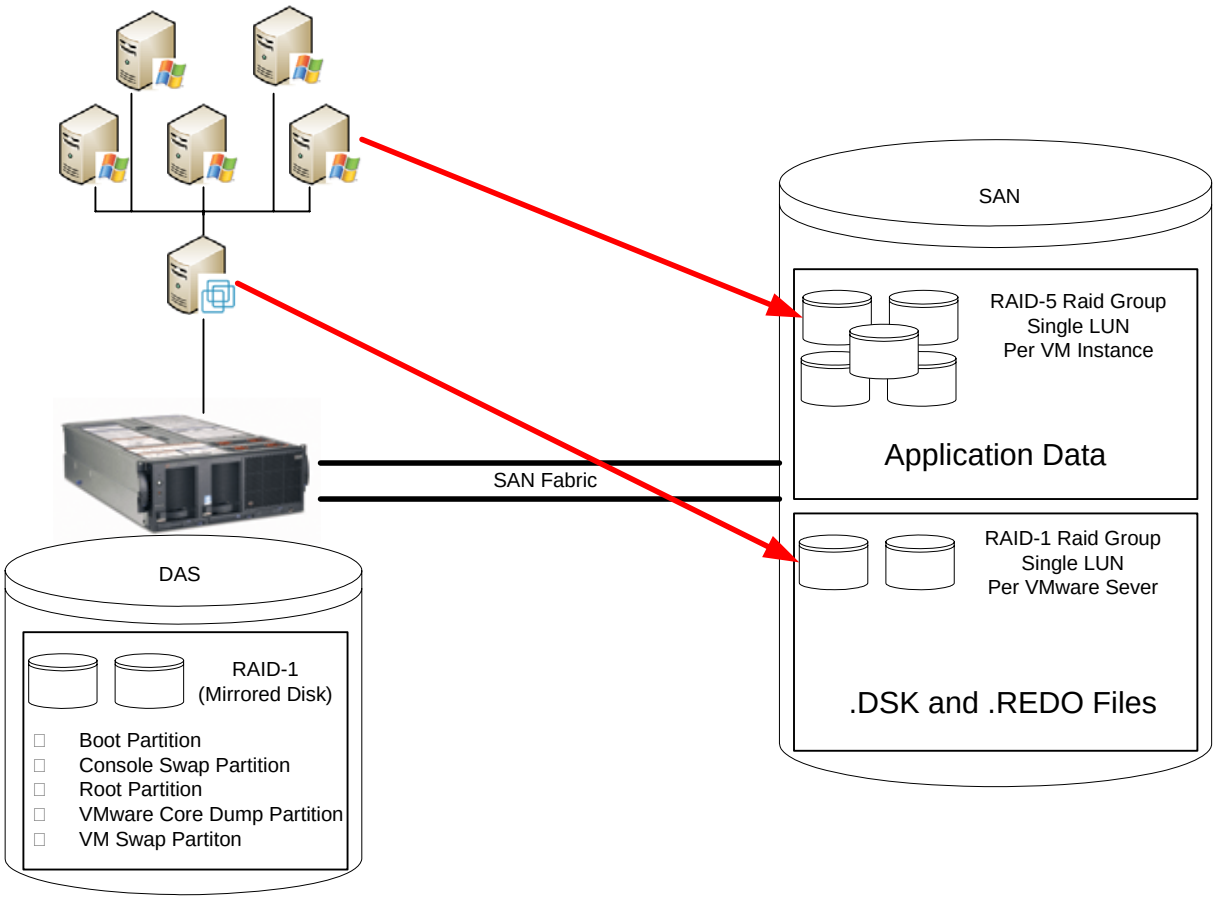

Figure XVI: Implementing VMware in SAN attached sites

If SAN is not attached on the site then it is recommended that NAS[67] be used to store the DSK files on one raid group and the data on another, using the same raid group configuration as shown above with the SAN storage.

The data requirements for the application will be met by storing the data either on the SAN as shown in the above diagram or by using an Enterprise NAS device. In both cases the data must be stored on a dedicated raid group for each virtual server. In most cases the choice will be determined by SAN fabric provision at the site. Where both are applicable it is suggested that SAN storage is used for the performance benefit that SAN gives over NAS.

[67] The use of specialized devices that function simply as hard drives connected to a network. NAS devices typically consist of one or more hard drives in a housing that contains a simple operating system and a network connection.

4.4.3 Disaster Recovery Configuration

Disaster recovery provision would be done utilising Microsoft Cluster Services between Virtual Server instances, where applicable, running in active-passive mode.

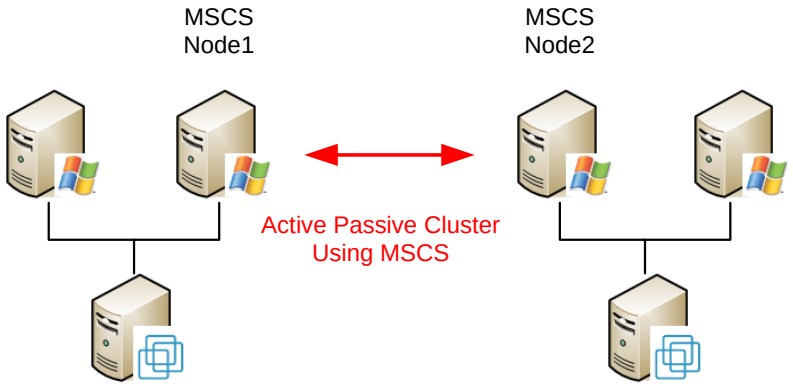

Figure XVII: Disaster Recovery Setup

For those applications that can not be run clustered it would be possible to maintain a duplicate of the DSK file and VMware instance configuration on a different server that could be commissioned in the event of a disaster to replace the original server. Both clustering and cold standby can be done within site or between sites dependant on the business or application requirement for site failure. It is assumed that a disaster recovery box would not contain non essential applications and therefore possibility for higher levels of consolidation would be more likely. This would mean fewer, but larger servers would be purchased. For example a Disaster recovery box might be an 8-way X445 that could provide disaster for two or three 4-way X445's. Disaster recover for the data on either SAN or NAS will be done in the same way as previously described.

4.4.4 Summary

The testing exercise lasted for around a month, involving system administrators and members of the Server Consolidation team. On its successful completion, Powergen decided to proceed with the server consolidation plans. This involved installing an

IBM X445 4-CPU server with VMware ESX Server software connected to an EMC Clarion CX600 SAN.

In the first phase of the server consolidation, ESX Server was installed on the IBM server, and one of the Windows 2000 Active Directories, which was running on a standalone server, was migrated to a VMware virtual machine. Then, a new application, Instant Messaging, was also deployed in the VMware environment. When no problems were encountered with these initial deployments, business critical & CPU intensive SQL database and middleware applications were migrated to the VMware platform.

Server Consolidation team member, Luke Lawrence explained that, due to the infancy of the technology and team members practical inexperience with the technology a cautious approach was taken to "build up confidence in the deployment of the technology." Initially setting up of the various virtual machines with the guest OS took three to four hours. Through familiarity with VMware, this has now been reduced to 15 minutes.

4.5 Validity of Results

Using Guba and Lincoln's (1994[68]) alternative method for assessing validity, the research validity was broken down into the following four areas:

4.5.1 Credibility[69]

Credibility from the standpoint of the respondents to the questionnaire was assured by emailing each individual within the Web Operations team. In this manner, only the required target population could respond. The transcript for the semi-structured

[68] Guba, E and Lincoln, Y (1994), *Handbook of Qualitative Research*, Newbury Park, pp105-117
[69] Credibility criteria involves establishing that the results of research are credible or believable from the perspective of the participant in the research.

interview was reviewed by the interviewee, Julie Windridge, who confirmed that these were her words.

Evaluating the credibility of results from the virtualization testbed is not necessarily applicable as credible and viable results are an outcome of the testbed itself.

4.5.2 Transferability[70]

Transferability of research may be considered limited due to the specialist nature of the questionnaire. However, the semi-structured interview with Julie Windridge comprised largely of generalized questions relating to project management within Powergen. A number of responses may be applied to other projects within Powergen.

The results of the testbed provide many generic solutions on the requirements and specifications for virtualisation deployment within any organisation which has a similar IT infrastructure.

4.5.3 Dependability[71]

Dependability is something which is highly applicable to any IT project. Staff variations (moving department, redundancy etc) may provide significant change to the outcome of questionnaire results, as the population changes in both numbers and individuals and therefore opinions. This is especially true when canvassing a limited number of people. However, as outlined within chapter three, the research approach taken for this study was cross-sectional, with the intention of establishing the respondent's viewpoint of the project at a specific time.

4.5.4 Confirmability[72]

[70] Transferability refers to the degree to which the results of research can be generalized or transferred to other contexts or settings.
[71] Dependability emphasizes the need for the researcher to account for the ever-changing context within which research occurs.
[72] Confirmability refers to the degree to which the results could be confirmed or corroborated by others.

Confirmability and credibility have a close tie within this study due to the nature of the approach taken for conducting the semi-structured interview (see Credibility above). All procedures for checking the data have been documented throughout the study. A data audit was conducted by two members of the Server Consolidation team to verify that the documenting of results from the testbed were accurate.

Chapter Five

Discussion

5.1 Introduction

This chapter will attempt to address the initial research objectives in section 1.3 of this report and evaluate against the research investigation to establish if the objectives have been realised.

5.2 Objective 1: Investigate the current project management practices at Powergen.

It is evident from the questionnaire that there are primarily two issues which should be duly noted of the methodology invoked in this study. These are People and Communication.

5.2.1 People

Although Powergen's project methodology is an adaptation of Prince2, there appears to be little evidence of softer issues included within this adaptation (see Appendix 3), with the procedural list consisting of a series of actions to be taken by the Project Manager whereas Prince2 believes that it is a mistake to neglect the 'people' part of the equation in favour of project management methodologies and tools and highlights that the quality of change capability can only be achieved through the "alignment, competency and attitudes of individuals and their project management skills." (Bentley 2002b[73]). As a direct result of this, the questionnaire highlighted the need for training amongst staff to be incorporated into the project model. Powergen encourages a 'shared learning' environment whereby members of each team are encouraged to work together, sharing knowledge. In practice, this does not always work as it is quite

[73] Bentley C. (2002) *Prince 2: A Practical Handbook*, 2nd Edition, Butterworth Heinemen, p48

common for the individual who has the required knowledge to be the most active and thus hardest to find.

5.2.2 Communication

Another issue highlighted by the questionnaire was awareness of the project. This issue can be considered directly related to that of people and training. The informal training methods imposed on staff can only be justified if there exists a strong communication channel amongst the team. Geographical issues currently prevent this from happening due to a location split of the Web Operations team. Although some members of staff travel to and from locations when deemed necessary, the majority of staff work within the one location this issue is exemplified in the response to question 13, demonstrated in the results section 4.3.1 There appears to be little formal communication on new projects and most information is passed via word-of-mouth which leads to the situation outlined above with many members of a team having little or no concept of a project which directly affects them.

5.3 Objective 2: Discuss the testing and implementation of VMware used by Powergen.

The primary deliverables and objectives for the testbed study were:
Procure, build and implement 2 x x445 IBM Servers which would run VMWare's Virtual Server Software. This infrastructure would be capable of hosting the entire instances of the existing 29 Servers, provide some resilience and provide some additional capacity for growth.

- Increase VMWare product knowledge prior to next Phases
- Monitor stability of the VMWare product
- Phased migration to reduce business/support impact
- Decommission existing infrastructure
- Free up racks/rack space in Sherwood Comms room
- Learn important lessons to assist with the next Phases

The purpose of the testlab was to ensure resilience and co-existence with existing architecture in an attempt to limit problems and conflicts with existing architecture after implementation. As the results have shown, all implementation methods were simulated, not just those which would be directly affected in the live environment.

However, the testbed also uncovered further benefits:

Because the operating system is essentially contained with a file it provides the unparalleled ability to create entire new server instances with hours rather than days and extremely simple ways of restoring the operating systems back to a known good state. This time for creation of new server instances was further decreased thorough the Server Consolidation team gaining a greater familiarity with the VMware system, effectively being able to create a new build within minutes. In addition, this is not just limited to server images; application suites can successfully be 'packaged' and run in a virtual machine.

Identified Benefits

- Restoration of failed operating system done by just restoring the operating system .DSK file to a known good state date.
- Isolation of operating system and application's. Application changes can be done without effecting other applications.
- Resource allocation allows for better utilisation levels
- Windows 2003 provides better performance & a more secure build out of the box
- Newer or better specification hardware.

Identified Risks

- Tighter Change Control required especially if changes are hardware
- More services effected by Hardware outage

- VMware virtualisation failure could cause all systems to fail.
- Capacity management requires full time attention

5.4 Objective 3: Analyse the capabilities and opportunities for deployment of virtualisation.

The opportunities for deployment are relatively limitless in terms of where in the network topology they can be deployed, as demonstrated in the results of the testbed, though the applications which reside on virtual servers impose restrictions in areas of compatibility and in terms of the support agreements with the various application vendors prior to moving the applications. However, most software vendors will support the use of VMware providing that in the event of a fault or issue, it can be proven that the fault also exists outside of the Virtual server session.

This method of consolidation was not a huge leap from the traditional "one-application per server" methodology that Powergen previously employed as applications can be deployed within isolated operating systems on the same hardware. The difference being that space, power and cooling consumption is greatly reduced as this solution requires less server hardware.

The basic capabilities of virtualisation as a server consolidation technology within Powergen have been realised through the successful implementation of the VMware pilot within the Web Operations team (consolidating the workloads of under-utilised servers). This also provides the related benefits of savings on hardware, environmental costs, management, and administration of the server infrastructure.

In a more generic sense, as the literature review demonstrates, VMware theoretically is capable of the following representative benefits:

The provision of secure, isolated 'sandboxes' by VMware (each OS instance) has a number of associated testing advantages, namely, ensuring quality assurance, fault

and error containment, isolating an environment from unknown/possibly harmful applications and debugging and performance monitoring provided by VMware tools.

Incompatibilities between new hardware and/or operating systems may render business critical legacy applications useless. Virtualising the old OS or hardware provides extended support for the application. In a similar vein, VMware may also provide the illusion of hardware or hardware configuration that is not physically owned.

Primarily however, the purpose of VMware should be to reduce complexity within an organisation by ensuring software is easier to migrate, backup and/or recover, thus aiding application and system mobility.

In conclusion, virtualisation as a solution, satisfied all the key deliverables laid out in the Problem Definition, section 2.5.

5.5 Objective 4: To draw conclusions and recommendations for future research.

Powergen plans to adopt a scale-up approach by adding more CPUs and RAM to the IBM X445 server, allowing it to support up to 30 virtual machines. At the time of piloting, virtual machines currently operated in a single-CPU mode. The next step Powergen will test is implementing ESX Server's Virtual SMP, which lets a virtual machine have symmetric multiprocessing capability with multiple CPUs for compute-intensive applications. Depending upon the outcome, Powergen will upgrade their physical server from 4-CPUs to 8-CPUs.

This study has provided an overview of the virtualisation process within an organisation. However, there are many areas still left uncovered which could provide interesting areas for further investigation. The concept of increasing a IT technican/administrator's workload by increasing the complexity of their working environment may provide an interesting insight into how the future of 'soft' issues in

IT are likely to be addressed. Technically, the infancy of VMware still means that most organisations are taking a cautious approach to server virtualisation. Future research on the nature of issues of a larger implementation would be a natural extension of this research.

The virtualisation industry in general looks to have a promising future as technology develops and matures. Further techniques include the ability to move the intelligence of virtualisation into network devices providing greater visibility on all servers and storage within the data centre. Advanced services can be incorporated into the network devices, delivering backup, mirroring, replication and management across systems, servers and storage.

Server virtualisation will increasingly play a pivotal role in helping enterprises fully utilise and consolidate hardware. For service providers, server virtualisation will redefine the industry by providing an automated infrastructure on which to create both new channels and a wide-range of virtual hosting plans.

5.6 Limitations of the Study

It is important to note that the research findings were possibly affected by the chosen research methods. One of the main drawbacks of the collection of primary data is the low response rate. A larger number of respondents, when issuing the questionnaire, would have undoubtedly provided more formative insights but due to time constraints this was not possible. Availability also played a prominent role when trying to arrange interviews and once again, this had an influence in the collection of primary data.

Chapter Six

Final Conclusions and Recommendations

6.1 Research Conclusion

The research undertaken in this study has not attempted to critique the application of virtualisation, but document the practical testing and application of VMware, providing background information on people's reaction to the perceived change through analysis of the Powergen Project Management methodology.

Although the literature review has already established that the drive towards consolidation of architecture is an industry trend, there seems little reason to doubt this is more than a passing phase within the IT sector. The benefits derived from adopting a virtualised infrastructure would appear to have few drawbacks with cost being the definitive gain. As the research demonstrates the timescale of the project from conception to implementation can be as little as one month, subject to the complexity of the initial virtualisation choice. However, as virtualisation technologies mature and more organisations choose to put faith in virtualisation as a viable strategy for consolidation, vendors of virtualisation software will undoubtedly increase in number with derived benefits far outweighing the cost of implementation for the customer.

6.2 Implications of Research Findings

Powergen's successful experience with server virtualisation would suggest that the technology is ready for open deployment.

The research findings highlight that through proper application of people, process and technology, server virtualisation technologies can be successfully deployed to achieve increased utilisation and greater flexibility. Additionally, through investment in server

virtualisation technologies, a technical foundation and experience can further the drive towards utility computing.

6.3 Closing Comments and Reflections

This project has proved immensely challenging both from a practical and academic perspective. The practical experience of developing a new system in a live situation from feasibility through to implementation represented a steep learning curve that was very intensive and highly rewarding.

The ability to transfer academic skills and knowledge acquired at university into a 'real world' situation was extremely pleasing. Application of these skills provided the opportunity to develop them further whilst gaining invaluable practical experience. Balancing the project with existing duties presented the chance to develop invaluable time management skills. Communication skills are also an area which has certainly been improved through the interaction of a wide range of people and their respective backgrounds.

On reflection, although a daunting task, the rewards of undergoing this project far outweigh the negatives and the knowledge taken from working within a great team on relatively cutting edge technology will undoubtedly be invaluable in whatever career awaits.

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Appendices

Figure	Title
1	Powergen Internal Communications, Platform Strategic Direction
2	Program of work for the Server Consolidation project
3	UKServices Project Management Procedures
4	Pilot Questionnaire
5	Questionnaire Covering Letter
6	Final Draft Questionnaire
7	Transcript of Semi-Structured interview with Julie Windridge
8	Results for the Web Operations questionnaire

Appendix 1:

Powergen Internal Communications,

Platform Strategic Direction

Appendix 2:

Program of work for

the Server Consolidation project

Appendix 3:

UKServices

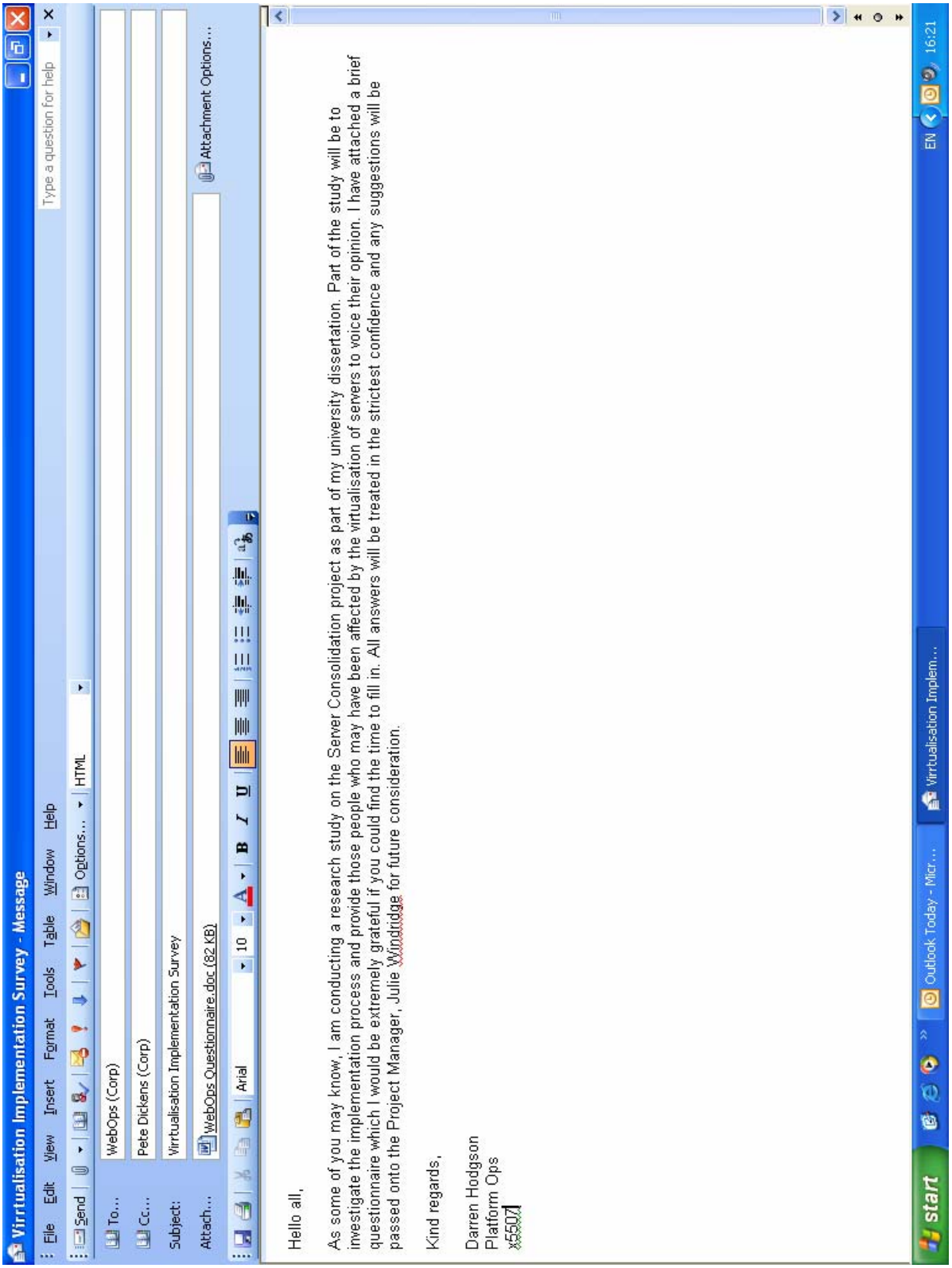
Project Management Procedures

Appendix 4:

Pilot Questionnaire

Appendix 5:

Questionnaire Covering Letter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10
Hello all,
As some of you may know, I am conducting a research study on the Server Consolidation project as part of my university dissertation. Part of the study will be to investigate the implementation process and provide those people who may have been affected by the virtualisation of servers to voice their opinion. I have attached a brief questionnaire which I would be extremely grateful if you could find the time to fill in. All answers will be treated in the strictest confidence and any suggestions will be passed onto the Project Manager, Julie Windridge for future consideration.
Kind regards,
Darren Hodgson
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Appendix 6:

Final Draft Questionnaire

Appendix 7:

Transcript of Semi-Structured interview with Julie Windridge

Appendix 8:

Results for the Web Operations Questionnaire

Appendix 9:

Alternative Consolidation Techniques

Alternative Consolidation Technologies

I have included this section to give an overview of the technologies Powergen will employ to successfully achieve consolidation

Microsoft Windows 2003 Server

This, the latest version of the Microsoft Windows Server platform has more improvements for performance, reliability and scalability than any other of its predecessors.
Windows Server 2003, Enterprise Edition, adds enhanced availability, scalability, and dependability—features also in Windows Server 2003, Datacenter Edition.

- Cluster service. Server clusters provide high availability and fault tolerance for mission-critical database management, file sharing, intranet data sharing, messaging, and general business applications. With Windows Server 2003, Enterprise Edition, and Windows Server 2003, Datacenter Edition, cluster service supports up to eight-node clusters for increased flexibility in adding and removing hardware in a geographically dispersed cluster environment. The cluster service also provides improved scaling options for applications. Windows Server 2003, Enterprise Edition, allows server clusters to be deployed in a variety of different configurations, in particular:
  - Single cluster configurations with dedicated storage.
  - Multiple clusters on a storage area network (SAN), potentially with other Windows–based servers or operating systems.
  - Clusters spanning multiple sites (that is, geographically dispersed clusters).
- Multiprocessor support. The Windows Server 2003 family scales from single-processor solutions all the way up to 32-way systems. Windows Server 2003, Enterprise Edition, supports servers with up to 8 processors, and Windows Server 2003, Datacenter Edition, supports up to 32 processors.
- Metadirectory Services support. Microsoft Metadirectory Services (MMS) helps organizations integrate identity information from multiple directories, databases, and files with Active Directory. MMS provides a unified view of identity information, enables the integration of business processes with MMS, and helps synchronize identity information across an organization.
- Hot Add Memory. Hot Add Memory allows ranges of memory to be added to a computer and made available to the operating system and applications as part of the normal memory pool. No rebooting and no downtime are required. This feature currently operates only on servers that have hardware support for adding memory while the server is operating. For these servers, the act of installing memory automatically invokes the Hot Add Memory feature in Windows Server 2003, Enterprise Edition. The IBM xSeries 440 and 445 servers support this functionality

- Non-Uniform Memory Access (NUMA). System firmware can create a table called the Static Resource Affinity Table that describes the NUMA topology of the system. Windows Server 2003, Enterprise Edition, uses this table to apply NUMA awareness to application processes, thread default affinity settings, thread scheduling, and memory management features. Additionally, the topology information is made available to applications using a set of NUMA application programming interfaces.
- Windows System Resource Manager. A feature in both Windows Server 2003, Enterprise Edition, and Windows Server 2003, Datacenter Edition, the Windows System Resource Manager (WSRM) enables an administrator to allocate CPU and memory utilization on a per-application basis. This is a useful tool for server consolidation.

IBM XSeries Architecture

AIM: Leveraging proven, innovative IBM technologies to build the most powerful, scalable, reliable Intel processor-based servers in the world

Guiding principles:

- Enhance and extend industry standards
- Drive down the total cost of IT
- Deliver OnForever™ computing (come as close as possible to achieving ZERO outages—scheduled or unscheduled)

X-Architecture™ technology is an evolving blueprint for IBM @server xSeries servers that are drawn from the vast enterprise server heritage of IBM. xSeries engineers take the technologies that have already revolutionized larger IBM systems and bring them to the Intel®-based platform. The results: industry-standard servers designed to provide enterprise-inspired power, scalability, control and service at very attractive prices.

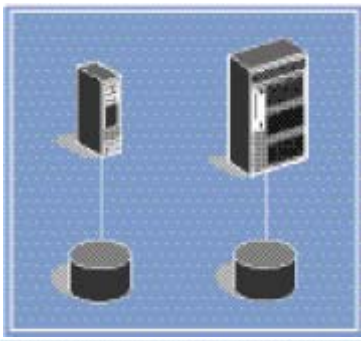
X-Architecture technology pulls together many of the best features of the other @server systems:

- Availability characteristics achieved by zSeries
- Scalability of the pSeries (512 - 1,024 node clusters of 8-way and soon, 12-way SMP systems)
- Solution relationships (25,000 application solutions) and self-maintaining capabilities (i.e., auto tuning, auto configuration) of the iSeries

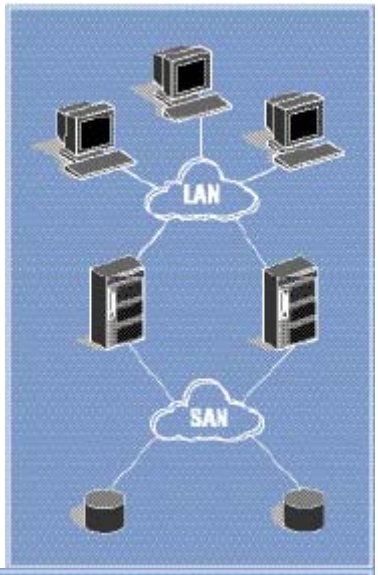
The strength of these technologies—and therefore of X-Architecture technology—lies in a research and development foundation that has no equal. For the past eight years, IBM has led the industry in number of patents acquired. We have continuously landed No. 1 benchmarks and pulled in a multitude of product awards. Now among those awards are titles won by xSeries servers.

IBM unleashes @server superiority on the Intel-based server market with its greatest wave of X-Architecture innovation to date. Called Enterprise X-Architecture technology, this new phase combines industry-standard technologies with IBM mainframe-inspired capabilities to produce revolutionary enhancements to I/O, memory and processors, as well as a true "pay as you grow" approach to buying Intel architecture 32-bit and 64-bit high-end xSeries systems. Enterprise X-Architecture technology is designed to achieve unparalleled levels of availability, scalability and performance in industry-standard enterprise computing.

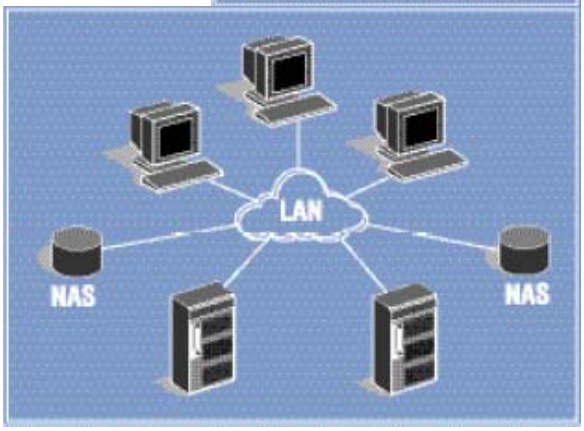
DAS / SAN / NAS



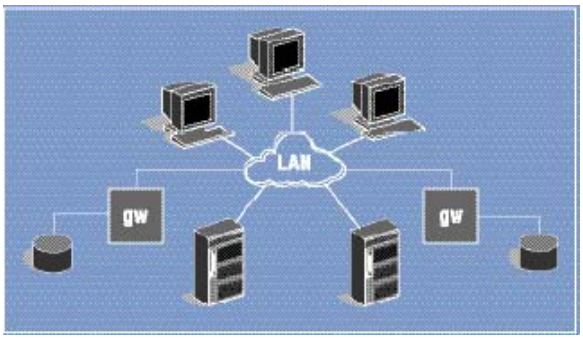
DAS: Direct Attached Storage. Storage (usually disk or tape) is directly attached by a cable to the computer processor. EG. The hard disk drives inside a PC, or a Disk array, attached to a single server are simple types of DAS. I/O requests accesses devices directly



SAN: Storage Area Network. Storage resides on a dedicated network. Like DAS, I/O requests access devices directly. Today, most SAN's use Fibre Channel media, providing an any-to-any connection for processors and storage on that network. Ethernet media using an I/O protocol called iSCSI is also available



NAS: Network Attached Storage. A NAS device ("appliance"), usually an integrated processor plus disk storage, is attached to a TCP/IP-based network (LAN or WAN), and accessed using specialized file access/file sharing protocols. File requests received by a NAS are translated by the internal processor to device requests.



NAS gateway:
A NAS device without integrated storage (i.e., just the NAS processor). Instead, the NAS device connects externally to storage by direct attachment or by a SAN.

Appendix 10:

Microsoft License Statements

Microsoft Statements

The below articles indicate Microsoft licensing and support stance on Partitioning and virtualisation.

License Position Regarding Per Processor Server Applications

Reference MS Licensing Web Site – Per processor Server Licensing Changes

Prior to the round of changes on April 1, 2003, for any given copy of server application software licensed on a per-processor basis, customers needed a license for each processor on the server on which that software copy is installed or run. Each copy of the software needed to be licensed separately. (A few exceptions existed, such as Microsoft® BizTalk® Server 2000 Standard Edition and SQL Server™ 2000 Enterprise Edition).

With the changes effective April 1 2003, for any software product licensed on a processor basis, customer still must acquire a license for each processor on the server; however, as an exception to that rule, customers do not need a license for any processor that has been made inaccessible to all operating system copies set up to run the software (e.g., through partitioning). Also, any number of copies of the software may be installed and run on a server provided the required number of processor licenses for that software has been acquired.

Two implications of these policy changes can be noted immediately: first, customers who partition their server hardware will now pay only for the processors that are used in support of the software, rather than every processor on the server. Second, the number of processor licenses required for a server application will not exceed the number of physical processors in the server.

The changes typically affect the volume licensing use rights for both the standard and enterprise editions (if applicable) of the currently available products licensed under the per-processor model, including:

- Microsoft® SQL Server™ 2000
- Microsoft® BizTalk® Server 2002
- Microsoft® Internet Security and Acceleration Server 2000
- Microsoft® Commerce Server 2002
- Microsoft® Content Management Server 2002
- Microsoft® Host Integration Server 2000
- Microsoft® Microsoft Operations Manager 2000
- Microsoft® Application Center 2000

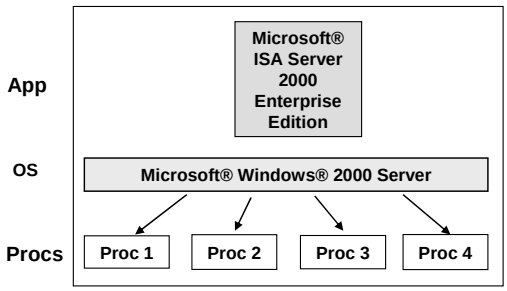
(Exception: The licensing changes discussed here do not apply Standard editions of all servers in the per-processor model; for example, the Standard edition of BizTalk Server still limits use to one copy for each processor. Customers' use of licensed software is subject to the terms and conditions of the license agreement, including the applicable Product Use Rights, under which they acquired it).

For customers with volume-licensing agreements who have existing processor licenses for the products listed above, Microsoft is extending an option to use the amended use rights in the April Product Use Rights document. Volume licensing customers may redeploy processor licenses "freed up" by the new policies. However, Microsoft will not extend any refunds or credits.

Sample Scenarios
To understand fully the implications of these changes to processor licensing, it may help to consider common scenarios for customer use of Microsoft server software. Below are 4 possibilities. With each scenario comes a rough diagram of the server components' arrangement, a breakdown of licensing requirements before and after April 1, and brief explanation of the dynamics affecting each scenario.

Please note that use of any per-processor server application in these scenarios, e.g. ISA Server in Scenario 1, or SQL Server in Scenario 2, and so on, is purely for illustrative purposes. These server applications can be interchanged in real-world applications of the licensing principles.

Scenario 1: Per-Processor Server Application Running on 4-Processor Server



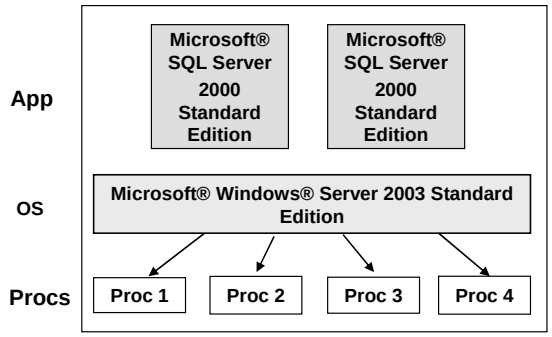
In this straightforward scenario, the implementation of the new per-processor rules does not change the licensing requirements for ISA Server. Each processor on the server requires an ISA Server processor license.

Microsoft Server Licensing Requirements

Product	Today	After April 1
Microsoft ISA Server 2000 Enterprise Edition	4 processor licenses	4 processor licenses
Microsoft Windows 2000 Server	1 server license *	1 server license *

* Windows 2000Server CALs are also needed for each device or user accessing Windows 2000Server

Scenario 2: 2 copies of a Per-Processor Server Application on a 4-Processor Server



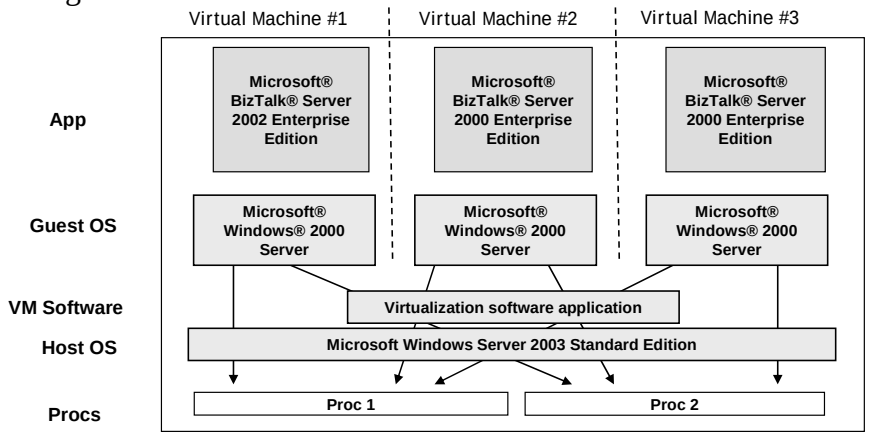
This scenario highlights one of the advantages of the new per-processor licensing model: Once the processors on a server are licensed for a server application (e.g., SQL Server 2000 Standard Edition), unlimited copies of that server application may be installed and run on that server. In effect, the number of processor licenses for a server application is capped at the number of physical processors on the machine.

Microsoft Server Licensing Requirements

Product	Today	After April 1
Microsoft SQL Server 2000 Standard Edition	8 processor licenses	4 processor licenses
Microsoft Windows Server 2003 Standard Edition	1 server license *	1 server license *

* Windows Server 2003 CALs are also needed for each device or user accessing Windows Server 2003

Scenario 3: 3 Per-Processor Server Applications Installed in Virtual Machines, Running on 2-Processor Server



Again, once the processors on a server have been properly licensed for a server application, unlimited copies of the server application may be installed and run on that server, even within virtual machines.

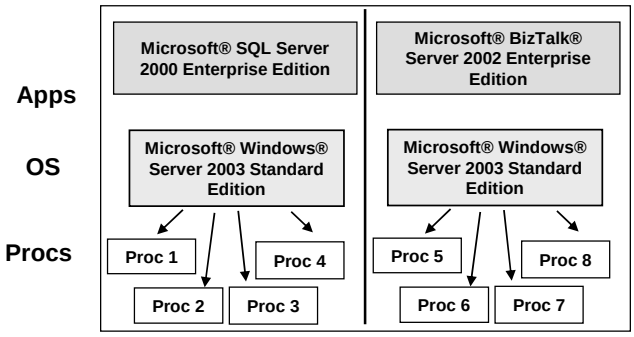
Each copy of Windows Server must be separately licensed.

Microsoft Server Licensing Requirements

Product	Today	After April 1
Microsoft BizTalk Server 2002 Enterprise Edition	6 processor licenses	2 processor licenses
Microsoft Windows Server 2003	1 server license *	1 server license *
Microsoft Windows 2000 Server	3 server licenses *	3 server licenses *

* Windows Server CALs are also needed for each device or user accessing Windows Server (CALs are version specific)

Scenario 4: 8-way Partitioned Server, with SQL Server and BizTalk Server Installed in 4-way Partitions



In this example, an 8-way server has been partitioned into two 4-way partitions. The processors in the left side partition are not accessible to the OS in the right side partition, and vice-versa. The new licensing rules are very beneficial. Only processors 1,2, 3, and 4 need SQL Server processor licenses. Only processors 5, 6, 7, and 8 need BizTalk Server processor licenses.

Each copy of Windows Server must be separately licensed.

Microsoft Server Licensing Requirements

Product	Today	After April 1
Microsoft SQL Server 2000 Enterprise Edition	8 processor licenses	4 processor licenses
Microsoft BizTalk Server 2002 Enterprise Edition	8 processor licenses	4 processor licenses
Microsoft Windows Server 2003 Standard Edition	2 server licenses	2 server licenses

* Windows Server 2003 CALs are also needed for each device or user accessing Windows Server 2003

License Position Regarding Virtualisation Technologies

Reference MS Licensing Web Site – Licensing in a Virtual Machine Environment

Definition of a Virtual Machine, and how it compares to Technology Alternatives
Virtualisation is a software technology that allows a user to create and run multiple operating environments on a server at the same time. Each operating environment, or virtual machine (VM), requires its own operating system and can run applications independently.
Virtualisation can be used to run different applications that are each compatible with different operating system (OS) versions on the same server. For example, an accounting system that requires Windows NT Server 4.0 might be installed on a virtual machine with a Windows NT 4.0 OS, even if the server on which the virtual machine is installed is running Windows 2000 Server. Virtualisation also might be used in a development environment to test applications on different operating systems. This brief describes virtualisation and alternative technologies, covers several volume licensing issues related to virtual machines, and offers answers to FAQs.

Virtualisation is one of several technologies that enable multiple applications and, in some cases, multiple operating systems to function simultaneously on the same hardware. The main alternatives to virtualisation are workload management and partitioning. Each offers a solution to a different set of customer needs.
Virtual machines offer maximum flexibility by giving system administrators a quick and easy way to establish different OS environments on a single physical machine. The OS environments are logically isolated from each other, but share many of the same hardware and software resources of the server, including its processors.

Consequently, a failure on any of these shared resources can affect multiple virtual machines.
Hardware partitioning, by contrast, creates blocks, or partitions, out of a single, multi-processor server, such that each will run its OS as if a physically separate machine. Unlike virtual machines, hardware partitions are physically isolated from each other and cannot share processors. Customers use this technology to avoid single points of failure. Hardware partitioning is generally less flexible than virtualisation, requiring a re-boot to set up or make changes, for example.

Workload management, the third method mentioned, allows for side-by-side execution of applications within a single OS environment with the system enforcing resource limits on each application. This technology can be used to increase overall system performance. It does not offer the ability to test or use applications in multiple OS environments. An example of resource-management technology is affinity masking.

Windows Server Licensing
Licensing Windows Server: Each copy of Microsoft Windows Server, whether used as the OS for a virtual machine ("guest OS") or as the OS for the server ("host OS"), must be separately licensed. For example, if a user is running Windows Server 2003 Enterprise Edition as a host OS on a server and creates two virtual machines, each with its own copy of Windows 2000 Server (each a guest OS), the user would require one Windows Server 2003 Enterprise Edition license and two Windows 2000 Server licenses.

CAL requirements: Each device or user accessing any copy of Windows Server (host OS or guest OS) requires a Windows Client Access License (CAL). The CAL must be of the same or later version as the software being accessed. So, for example, if a user accesses both Windows Server 2003 and Windows 2000 Server, the user must have a Windows Server 2003 CAL. Such a CAL permits access to Windows Server 2003 and any previous version of the software. Conversely, a Windows 2000 Server CAL would not permit access to Windows Server 2003.

Downgrade rights: Windows 2000 Server and Windows Server 2003 licenses acquired through volume licensing or retail permit a downgrade to an earlier version of the server software. For example, a customer with a Windows Server 2003 Standard Edition license can install and run a copy of Windows 2000 Server, or Windows NT Server 4.0 Standard Edition, in place of Windows Server 2003 Standard Edition. Only one copy of Windows Server may be installed under a single license. Downgrade rights may also be beneficial to customers licensing later versions of Windows Server who wish to consolidate older applications onto a virtual machine.

Server Application Licensing
Licensing servers under a per-processor model: Microsoft announced changes to its per-processor licensing model for servers, effective April 1, 2003. The new model can benefit virtual-machine users. In general, for any server software licensed on a processor basis, a customer must acquire a license for that software for each processor on a server. As an exception, if the customer has made any processor on the server

inaccessible to all of the operating systems set up to run the software (e.g., through partitioning), then the customer does not need a server software license for that processor. Additionally, a customer may install and run any number of copies of the server software provided the required number of processor licenses has been acquired. This last rule significantly benefits customers who install and run the server software on multiple virtual machines on the same processors. Please refer to the Microsoft Product Use Rights for more details.

Examples of Microsoft server software licensed in the per-processor model that will benefit from the recent changes (changes apply to both Standard and Enterprise editions, where applicable, unless otherwise noted in the software's product use rights or license agreement):

- Microsoft® Application Center 2000
- Microsoft® BizTalk® Server 2002
- Microsoft® Commerce Server 2002
- Microsoft® Content Management Server 2002
- Microsoft® Host Integration Server 2000
- Microsoft® Internet Security and Acceleration Server
- Microsoft® Operations Manager 2000
- Microsoft® SQL Server™ 2000 (only when licensed in per-processor mode)

Licensing servers under a server/ CAL model: Generally, server application products licensed on the server/CAL model are licensed similar to Windows Server. That is, each installed copy of the server software must be separately licensed, whether the copy is installed via a virtual machine or on the server. Please see Microsoft Product Use Rights for more details.

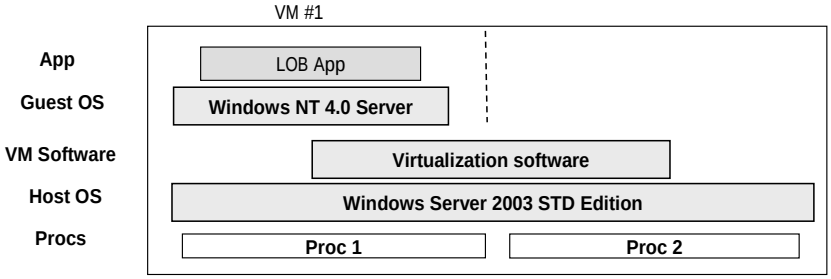
Generally, each device or user accessing any copy of server software licensed in a server/CAL model (whether the copy is installed on a virtual machine or directly on the server) requires a CAL for that server software.

Examples of Microsoft server software licensed in the server/CAL model are:

- Microsoft® Exchange Server
- Microsoft® Project Server
- Microsoft® Sharepoint Portal Server
- Microsoft® SQL Server™ (only when licensed in the per seat mode)
- Microsoft® Systems Management Server
- Microsoft® Windows® Server

Examples of virtualisation:

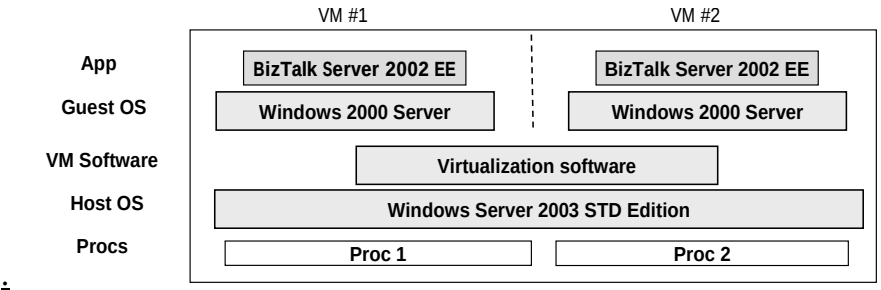
Scenario 1: Customer migrates a legacy line-of-business (LOB) application from a 1-way server running Windows NT 4.0 onto a 2-way server running Windows Server 2003 with a virtual machine running Windows NT 4.0.



Microsoft Product License Requirements

Product	# of Licenses Required
Windows Server 2003 STD	1 Server License
Windows NT 4.0 Server	1 Server License

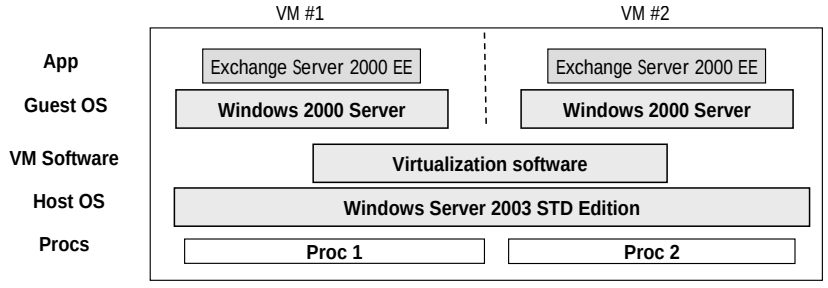
Scenario 2: Customer deploys Windows BizTalk Server 2002 Enterprise Edition on 2 virtual machines. Each virtual machine is running Windows 2000 Server and the server is running Windows Server 2003 Standard Edition. Each copy of Window 2000 Server on the virtual machines uses both processors in the server



Microsoft Product License Requirements

Product	# of Licenses Required
Windows Server 2003 STD	1 Server License
Windows 2000 Server	2 Server Licenses
BizTalk Server 2002 Ent Edt	2 Processor Licenses

Scenario 3: Customer performs pre-deployment configuration testing with Exchange Server 2000 Enterprise Edition on 2 virtual machines. Each virtual machine is running Windows 2000 Server and the server is running Windows Server 2003 Standard Edition. Each copy of Window 2000 Server on the virtual machines uses both processors in the server.



Microsoft Product License Requirements

Product	# of Licenses Required
Windows Server 2003 STD	1 Server License
Windows 2000 Server	2 Server Licenses
Exchange 2000 Ent Edt	2 Server Licenses

Support Position Regarding VMware products

Reference MSKB Article 273508

VMware Support Policy and Support Boundaries
The information in this article applies to:

- Microsoft Windows 2000 Server
- Microsoft Windows 2000 Advanced Server
- Microsoft Windows 2000 Professional
- Microsoft Windows NT Server 4.0
- Microsoft Windows NT Workstation 4.0
- Microsoft Windows XP Home Edition
- Microsoft Windows XP Professional
- Microsoft Windows XP Tablet PC Edition
- Microsoft Windows XP Media Center Edition
- Microsoft Windows XP 64-Bit Edition Version 2002
- Microsoft Windows XP 64-Bit Edition Version 2003
- Microsoft Windows Server 2003, 64-Bit Datacenter Edition
- Microsoft Windows Server 2003, 64-Bit Enterprise Edition
- Microsoft Windows Server 2003, Datacenter Edition
- Microsoft Windows Server 2003, Enterprise Edition
- Microsoft Windows Server 2003, Standard Edition
- Microsoft Windows Server 2003, Web Edition

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SUMMARY
VMware produces a suite of products that includes VMware Server, GSX VMware Server ESX, and VMware Workstation. When you use VMware, you can run additional operating systems in multiple windows that are called virtual machines.

Microsoft does not support issues that occur in Microsoft operating systems or programs that run in a virtual machine until it is determined that the same issue can be reproduced outside the virtual machine environment.

MORE INFORMATION
For information about how to obtain VMware support, visit the following VMware Web site:
http://www.vmware.com
Microsoft provides third-party contact information to help you find technical support. This contact information may change without notice. Microsoft does not guarantee the

accuracy of this third-party contact information.

The third-party products that are discussed in this article are manufactured by companies that are independent of Microsoft. Microsoft makes no warranty, implied or otherwise, regarding the performance or reliability of these products.

Appendix 11:

VMware Support Options

VMware Support Options

VMware provides a variety of support options. ESX Server is sold with VMware Premium Support and Subscription Programs. There are three packages available, depending upon the level of support you require.

	Silver	Gold	Platinum
Contract Term	1 Year	1 Year	1 Year
Access Channels	Web Only	Web & Phone	Web & Phone
Coverage Hours	12X5	12X5	24X7
Response Time	One business day	Four business hours for P1 request. One business day for all other requests	Four business hours for P1 request. One business day for all other requests
Request limits	Unlimited	Unlimited	Unlimited
Escalation/On site	N/A	N/A	Available

Free support is available on the Web site in the form of FAQs and searchable knowledge base. Go to: http://www.vmware.com/support/