Research Report

Server virtualization maturity study

Recommended procedures and controls that minimize risk of virtualizing business critical systems

Based on 15 executive interviews and analysis of data from 323 IT organizations

Recommendations in this research report are based on a post-implementation analysis of data from 323 IT organizations. The study goal was to better understand the impact of virtualization on datacenter operating practices. Analysis and resulting recommendations are not product focused. This report identifies specific procedures and controls that should be considered to reduce risk as organizations virtualize business critical systems, and when evolving production virtualization objectives beyond server consolidation, to high availability and disaster recovery, and dynamic resource management scenarios.

Those responsible for datacenter operations and performance can match the lists of recommended practices to current and future production server virtualization objectives. IT audit professionals can use the lists of practices to evaluate and modify IT control requirements, and update IT audit checklists.

This independent research study was funded by the generous support of our managing sponsors Protiviti and CA, and project sponsor VMware.

Advancing the Science of IT Management

IT Process Institute
www.itpi.org

Data was collected from 323 IT organizations by custom research firm HANSA/GCR. A web-based survey, based on findings from 15 executive interviews, was used to collect data in October 2008. The survey respondents were invited from the HANSA/GCR North American IT executive interview panel.

Benchmarking Tool

This report allows readers to mentally compare their use of recommended practices to 323 other organizations in the study. However, for a more detailed comparison, the IT Process Institute offers the Server Virtualization Control Benchmark as a companion tool to this research report. The benchmark is a simple but powerful web-based tool that can be used to compare an IT organization's use of 51 server virtualization practices, 11 hard performance measures, and 10 soft outcomes measures, to 323 baseline maturity and high maturity organizations in the study. The benchmark allows users to compare to other organizations based on virtualization objectives. http://www.itpi.org/home/benchmarking.php.

Acknowledgements

Special thanks to the following individuals that provided feedback on draft versions of this report.

- Sarah Keller-Weir, Protiviti
- Steve Darby, VP operations IP Services
- Susheel Mannepalli

About the Author

Kurt Milne is the managing director of the IT Process Institute. He has 20 years of experience at leading technology companies including Hewlett Packard and BMC Software. His main areas of expertise include IT service management and IT controls, inventory and supply chain management, and computer integrated manufacturing.

About the IT Process Institute

The IT Process Institute is an independent research organization that exists to advance IT management science through independent research, benchmarking, and development of prescriptive guidance. Our vision is to identify practices that are proven to improve the performance of IT organizations. www.itpi.org

Executive Summary

The IT Process Institute conducted a post-implementation study of server virtualization procedures and controls to find out what operating changes IT organizations make to optimize benefit and reduce risk in production datacenter environments.

Based on 15 executive interviews, and analysis of data collected data from 323 IT organizations, we identified three sets of recommended practices:

- **Baseline maturity practices** – 11 practices recommended for those organizations consolidating servers and virtualizing business critical systems in the production environment. Focus improvements in the areas of host access and configuration controls, virtual machine provisioning, and capacity and performance management.
- **High maturity static practices** – 25 recommended practices for those organizations expanding beyond server consolidation to high availability and disaster recovery objectives in an otherwise static environment. Focus improvements on quickly responding to performance impacting conditions with a high degree of configuration standardization, provisioning with approved build images, and using a "trust but verify" strategy for change process and configuration compliance.
- **High maturity dynamic practices** – 12 recommended practices for those organizations pursuing dynamic resource management objectives. Incremental controls primarily in the area of configuration discovery and tracking, change approval, capacity and performance management, and overall process maturity needed to support automation.

Key findings:

- 72% of study participants are aggressively virtualizing production servers. Of those, 58% had at one point paused adoption to improve operating procedures, and 64% are now comfortable virtualizing business critical systems.
- Of the study population 19% are only pursuing server consolidation objectives, 22% are also pursuing high availability and disaster recovery objectives, and 31% are pursuing dynamic resource optimization objectives.
- The maturity of use of 51 related virtualization management procedures and controls correlates with objectives.
    - Organizations aggressively consolidating production servers, average 45% of tested practices in use.
    - Organizations with high availability, disaster recovery and dynamic resource objectives, average 69% of tested practices in use.
- Overall, the use of production virtualization does require changes to operating procedures and controls.
- Those organizations with a strong foundation of process controls and best practices procedures may only need to modify controls in a few areas to pursue consolidation objectives. However, those pursuing higher maturity objectives should consider additional procedures and controls.

Table of Contents

List of Figures

Managing risk in production

Adoption of virtualization technology is expanding rapidly. Many organizations are aggressively consolidating underutilized servers to reduce hardware and power costs. Increasingly, IT organizations are moving beyond consolidation to high availability and disaster recovery objectives. They are also using virtualization to dynamically move and expand resources to increase agility and extend consolidation efficiency gains. Many view automation used to manage dynamic virtual resources as a prerequisite for tapping internal and external cloud computing resources.

Virtualization is also expanding across layers in the computing stack. Virtualized storage, networking, security tools are increasingly utilized. Virtualized desktops in a variety of forms are being deployed to increase centralized control of endpoint computing devices as well as optimize user experience. Application virtualization promises to further extend centralized IT control, significantly reducing application conflicts, and optimizing deployment, patch, and upgrade processes.

Virtualizing business-critical systems

However, as IT organizations move virtualization from test and development into production environments, there is often an evaluation period to assess risk and identify security and operational impact. In fact 58% of the organizations with the highest level of virtualization maturity in this study have at one point had a limited production release of virtualization (i.e. limited rollout) until training requirements and specific virtualization management procedures were identified.[1]

Many IT organizations are aggressively virtualizing business critical systems

The good news is that many IT organizations have now reached the level of confidence needed to aggressively virtualize business critical systems, including those that are in scope for regulatory compliance. Sixty four percent of the organizations in this study that are aggressively pursuing production virtualization indicate they are comfortable virtualizing business critical systems.[2] Sixty nine percent have virtualized systems that are in scope for audit and compliance.[3]

Virtualization has enabled a fundamental shift in managing IT resources. But does the use of virtualization in the production environment also require a fundamental shift in operational process and procedures? Does virtualization hinder or enhance existing IT control requirements?

To get comfortable with virtualization, those responsible for datacenter operating performance and service levels should consider the risks and operational impact in addition to the promised benefits of this game changing technology. What IT management process, procedures and controls need to be in place in order to "get comfortable" virtualizing business critical systems?

Virtualization Risks

The benefits of virtualization are compelling. However, there are risks associated with virtualization. Anecdotal evidence collected from 15 IT executives during this study indicates a range of potential issues with operating practices and procedures used to manage this powerful technology.

Summary of risks:

- Virtual sprawl – the ease and speed at which systems can be provisioned and moved can make it difficult to keep track of virtualized resources. If production virtualization is implemented without rigorous change controls, IT organizations can lose track of virtual resources reducing the consolidation benefits of virtualization.
- Discovery – there are multiple potential issues with discovery tools designed to work with non-virtualized systems. Virtualization can hide traditional discovery targets compounding virtual sprawl issues.
- Copy and propagate – the ease of replicating and moving applications within a virtual environment increases license compliance risk. Careful control of image build process minimizes software license compliance risk.
- Single point of failure – multiple virtual servers on a single host server creates the risk that host maintenance activities might cause multiple servers and applications to fail. Well meaning administrators can make configuration and setting changes that have critical consequences for all applications on the host.
- Configuration and change compliance – virtualized "in scope" business systems have higher requirements for controlling and verifying system management activities. Virtualization technology can both hinder and enhance compliance efforts depending on how it is managed.
- Capacity and performance – virtualization allows multiple operating systems and applications to run on a single host machine. This improves overall machine resource utilization, but also creates risk of exceeding available resource capacity.
- Complexity – virtualization simplifies many common datacenter activities. But it also creates a new technology layer that must be managed. Aggressive adoption of virtualization may require specialized training and new organizational structures.
- Security – hypervisor layer represents a new layer of technology that can be attacked. External threats can propagate within virtual environments. However, virtual resource security risks can be mitigated.

Virtualizing business critical systems without operational controls creates unacceptable risk

The general consensus of IT executives interviewed is that putting virtualized systems in production without a well reasoned set of operational controls, creates an unacceptable level of production and compliance risk.

What do we need to do?

The basic question that frames the analysis of this study is: "What operational practices, procedures, and controls are needed to address the potential risk of virtualizing business critical systems?

IT executives we interviewed who have not yet aggressively virtualized production systems wanted to know what others have done to "get comfortable" virtualizing business critical systems.

Other IT executives who are comfortable aggressively consolidating production servers want to know what to expect as they expand their use of virtualization. Are there advanced operational practices that help manage risk as they move beyond consolidation to high availability, disaster recovery, and dynamic resource allocation objectives?

Study methodology

To answer these questions we interviewed 15 IT executives from organizations at different stages of virtualization deployment to ask "what specific process and procedure based controls changed when moving virtualization into production?"

Based on changes identified in during the interviews, we developed a web-based survey to collect data about the use of various practices from a broad sample of IT organizations. Custom research firm HANSA/GCR deployed a web-based survey and managed data collection in October 2008. The survey respondents were invited from HANSA/GCR North American IT executive interview panels. Detailed study demographics are included in Appendix B.

We collected data from 323 IT organizations primarily in North America about use of 51 different server virtualization practices, 12 hard performance measures, and 9 soft outcomes measures. We also collected firmagraphic data about other IT operating statistics to help profile respondents at different levels of virtualization maturity.

A summary of the scope of survey questions is shown in Figure 1.

Virtualization Procedures and Controls (51)	Hard Performance Measures (11)
Host access and configuration controls (9)	Resource utilization (2)
Virtual Machine provisioning (8)	Change and release management (4)
Configuration discovery and tracking (8)	Service and support (3)
Change management (7)	Configuration control (2)
Failover and disaster recovery (4)	
Capacity and performance management (6)	Soft performance measures (10)
Risk and audit (4)	Sprawl and variance (2)
Other (5)	Agility and effort (3)
	Automation (2)
	Risk and control (3)

Figure 1 - Summary of survey data collected

By comparing the use of procedures and controls of organizations that have not yet moved virtualization into production with those that have, we identified recommended baseline practices for production server consolidation. We also compare practices in use by groups of organizations pursuing more advanced virtualization objectives, to identify high maturity recommended practices.

We also analyze soft and hard performance measures to determine which practices have the biggest performance improvement potential.

The study and survey questions are not product focused. Respondents used virtualization technology from a wide range of vendors. This study and recommended practices is instead focused on operating processes, procedures, and controls related to production virtualization.

Determining production virtualization maturity

The use of virtualization in production is maturing. Organizations are moving beyond the initial cost savings and consolidation focus, and are leveraging use of the technology to meet other high availability and resource agility objectives. A recent customer survey by VMWare indicates that improved business continuity and disaster recovery has risen in importance, and surpassed server consolidation as the most frequent datacenter virtualization objective.[4]

Assess production server virtualization objectives

To understand the mix of virtualization deployment objectives, we asked "What is your organization's status of production server virtualization?" Figure 2 indicates a mix of responses ranging from aggressively deployed in production, to tentatively deployed, evaluation and consideration, or not considering.

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Aggressively deployed in production	193	142	101
Tentatively deployed – still working on policies, procedures, training	66	91	100
Evaluation or POC	35	50	56
Actively Considering	19	27	41
Not Considering	10	13	25
	(323)	(323)	(323)

Figure 2 – Status of production server virtualization objectives

OS consolidation has the highest rate aggressively deployed in production, and lowest rate tentatively deployed. Failover and disaster recovery has second highest rate of aggressive deployment followed by dynamic capacity. These findings confirm both what we heard in executive interviews and the VWmare study findings.

To study the use of virtualization practices related to different virtualization objectives, we grouped respondents based on which of the three areas they were aggressively deployed in production. We separated those not yet aggressive in production in any area, from those aggressive only in the area of OS consolidation, from those deploying any combination of failover or disaster recovery, and dynamic capacity allocation. Figure 3 shows these three groupings.

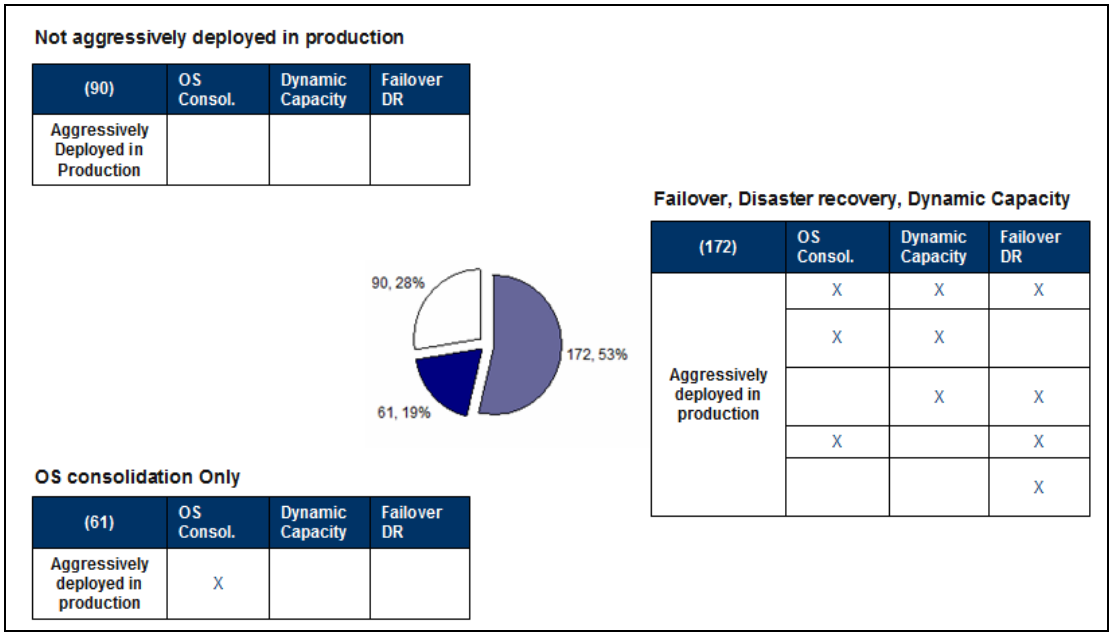


Figure 3 – Three groups of respondents based on virtualization objectives.

Based on the responses, 28% of the study sample is using server virtualization, but not yet aggressive in production environment. An additional 19% of organizations are only aggressively pursuing production OS consolidation objectives. The other 53% of study participants have moved beyond OS consolidation objectives, and are also pursuing failover, disaster recover, or dynamic capacity objectives. Note that 9% of study participants indicated that they are aggressively pursing failover and disaster recovery in production, but not aggressively pursuing OS consolidation, or dynamic capacity.

Server virtualization operational maturity

The operational maturity of the different groups of organizations was determined by measuring the level of use of various virtualization practices in eight areas including:

1) Host access and configuration controls
2) Virtual machine provisioning
3) Configuration discovery and tracking
4) Change management
5) Failover and disaster recovery
6) Capacity and performance management
7) Risk and audit
8) Other

Respondents answered likert scale survey questions applied to 51 server virtualization practices: "For each process, procedure, or control, please indicate your level of agreement using the following scale".

1) Not doing this at all in our organization	2) Doing this inconsistently/ at few locations	3) Doing this somewhat consistently/ at some locations	4) Doing this consistently/ at many locations	5) Doing this very consistently across our entire organization

Figure 4 – shows the combined average percentage answers at each of levels 1 through 5 for all 51 practice questions, for each group separated by objective.

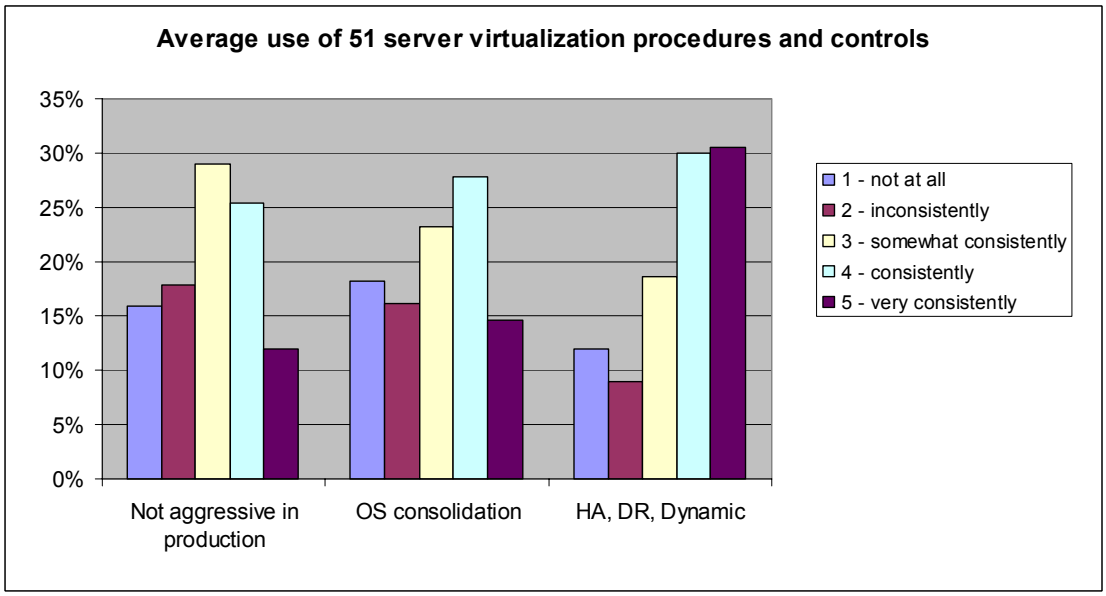


Figure 4 – Average level of use of server virtualization procedures and controls

The average percentage of 51 server virtualization practices at 4 and 5 level, what are considered "in use", are higher for production OS consolidation group (45%) as compared to those not yet aggressively using virtualization in production (41%). Those pursuing more advanced virtualization objectives average 69% of practices in use at level 4 and 5.

Overall, maturity of use of virtualization practices correlates with grouping based on production virtualization objectives.

Maturity of use of practices correlates with virtualization objectives

We label two levels of production virtualization maturity: 1) baseline maturity, which includes those organizations aggressively implementing OS consolidation, and 2) high maturity, which includes those pursuing virtualization based failover, disaster recovery, and dynamic capacity.

Figure 5 shows summary scores for the not yet in production, as well as baseline and high production maturity groups.

Maturity group	Percent of 51 practices "in use" (level 4or 5)
High maturity	69%
Baseline maturity	45%
Not in production	41%

Figure 5 – Three server virtualization maturity groups

Recommended practices - baseline maturity

Statistical analysis reveal practices implemented at lower levels of usage in the non-production group as compared to the baseline and high maturity groups.[5] We also identified practices that at least 50% the baseline and high maturity groups have in use at level 4 or 5. We combined these lists to identify recommended baseline practices that should be considered when moving virtualized systems into a production environment, or virtualizing business critical systems.

Figure 6 shows the percentage of respondents in each group that scored 4 or 5 in each of eight server virtualization practice areas.

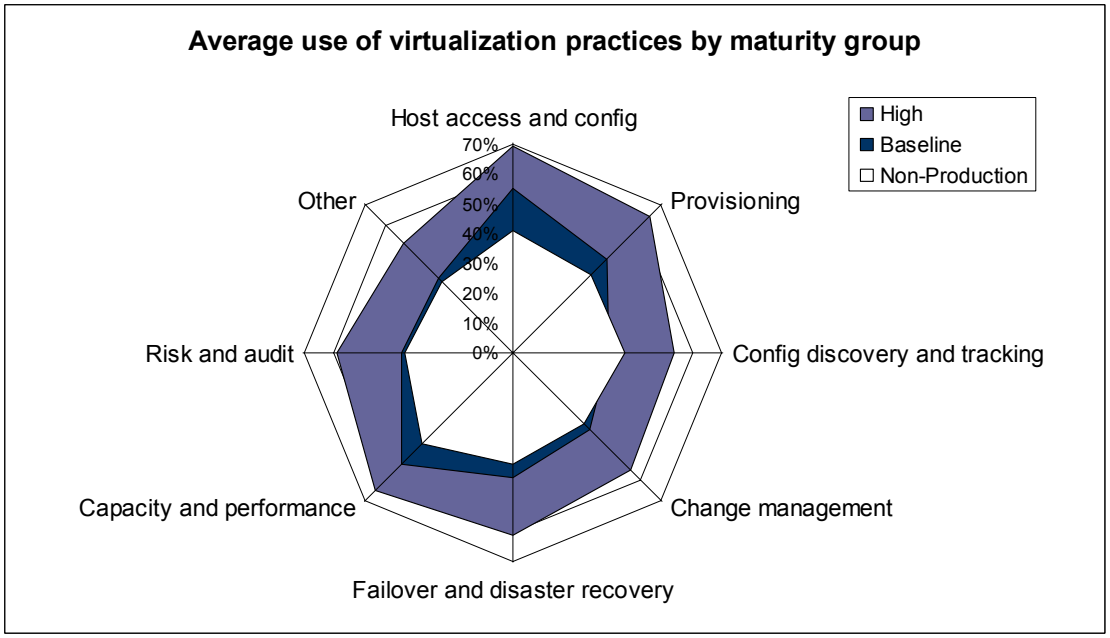


Figure 6 – Percentage of maturity groups that have virtualization practices "In use"

Analysis reveals 11 recommended baseline maturity practices in three areas of host access and configuration controls, virtual machine provisioning, and capacity and performance management.

These baseline practices, shown in Figure 7 should be considered by organizations consolidating production servers, and virtualizing business critical systems. The high maturity group has 9 of the 11 practices in use at more than 70% of organizations, indicated by "*".

Recommended Baseline Maturity Practices

Host access and configuration controls
1. * Use roles based access policies so that the virtualized host administrator role is identified.
2. * Rigorously control access and restrict privileged access to production host environment.
3. * Clearly document host administrator and host maintenance procedures.
4. * Identify and document configuration standards for the host OS.
5. * Identified and use host security and configuration hardening guidelines.
Virtual Machine Provisioning
6. * Strictly follow a formal change process to manage virtual environment provisioning.
7. * Define and enforce image build process for provisioning virtual server environments.
8. Provision new virtual servers using standard images (i.e. golden builds).
Capacity and performance management
9. Actively monitor the capacity and performance of virtual machines so that resource constraints are identified and addressed.
10. * Actively monitor the capacity and performance of host resources.
11. * Carefully consider capacity issues when making targeting and move decisions.
* practice in use by more than 70% of high maturity organizations

Figure 7– List of 11 recommend baseline maturity practices

For example, 77% of production high maturity group have the baseline practice number 4 "Identify and document configuration standards for the host OS" in use, as compared to 66% of baseline maturity group, and 44% of non-production group.

Note – only 33 % of the baseline maturity group are virtualizing on multiple platforms (ie Windows) that require the use of various performance management tools, as compared to 48% of high maturity group.[6]

Also note – 62% of baseline maturity and high maturity groups use tools to patch and update virtual host other than those provided by the vendor, as compared to only 38% of those not yet in production.[7]

There are numerous considerations when virtualizing production and business critical systems. We consider this a minimum list of recommended practices for server virtualization in the production environment based on the use of practices of the 323 organizations in the study.

Comments on recommended baseline maturity practices

A number of interviewed IT executives indicated that "not much changed when we moved virtualization into production" from a controls and procedures standpoint. Those organizations were using virtualization to consolidate servers without dynamic provisioning and virtual machine movement.

In general these organizations felt like they had strong access, change and configuration controls managing their production environment. Moving multiple virtual servers onto a single host server in a static environment didn't require major

changes to existing controls. They were able to modify and extend existing production best practices to manage new virtualization technology in production.

The baseline maturity recommended practices represent an extension of best practice controls identified in other ITPI studies. ITPI studies have identified foundational access, change, configuration and release foundational controls that have a significant impact on operating performance in a dedicated host environment.[8]

For example, adding a hypervisor to production server requires identifying a new administrator role, and restricting admin rights to the host server. Host maintenance procedures should be well documented to minimize risk of unintended consequences of administrator activities that create a single point of failure for multiple virtual machines. Host security configuration guidelines are now widely available from virtualization vendors as well as organizations like Center for Internet Security, that can be used to identify host configuration standards that optimize security.[9]

Similarly, provisioning controls identified in this study are also an extension of dedicated host configuration best practices. Strictly following a formal change process for all production environment changes is a baseline control that should be rigorously enforce at any organization serious about service levels and production security and reliability, regardless of use of virtualization. Carefully controlling virtual system changes can be handled by existing procedural controls at many top performing organizations.

Note ITPI's recommends that change detection tools that identify configuration drift are needed to implement an effective change control process. Well designed policies that encourage compliance are also recommended. Although analysis in this study reveals these controls as a high maturity practices, we recommend all organizations implement change detection and consequences in order to encourage chance process compliance.

Defining and enforcing image build process, and provisioning virtual servers using those standard images help reduce configuration variance. The ease of deploying virtual environments actually makes it easier to implement this widely recognized production systems management best practice.

Capacity and performance management practices may represent the biggest departure from dedicated server management practices. Many systems that are consolidated onto a common host were provisioned with excess capacity. Combining those systems on a single host enables better resource utilization, but may impact performance if host resources are fully utilized. Carefully monitoring and managing host and virtual machine performance and capacity may be a new area of focus for systems that were previously lightly monitored. Resource allocation settings for the virtual host need to be carefully considered. The capacity and performance of host and virtual machines should be carefully evaluated when making targeting and move decisions for consolidated servers.

Recommended practices - high maturity static

Statistical analysis reveal practices implemented at lower frequency in the production baseline group than with the high maturity organizations that are aggressively virtualizing production systems for failover, disaster recover, and dynamic provisioning objectives.[10]

Figure 8 shows the percentage of respondents in each group that scored 4 or 5 in each of eight server virtualization practice areas.

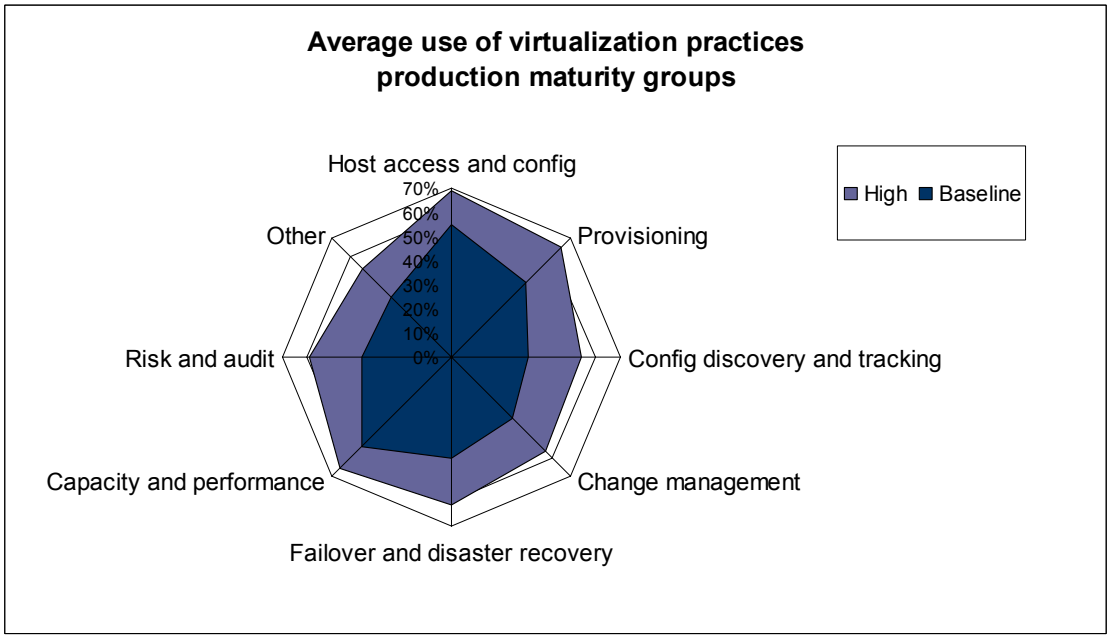


Figure 8 - Percentage of production groups with virtualization practices "In use"

Analysis revealed 25 practices in all 8 areas that in use at a higher frequency in the high maturity group than the baseline maturity group. These recommended production high maturity practices are listed in Figure 9. Two of practices in use at more than 70% of high maturity organizations, indicated by "*".

Recommended Production High Maturity Static Practices

Host access and configuration controls
1. Identify a level of training required to receive host privileged access.
2. Enforce segregation of duties so that those with host access are different than those with virtual machine privileged access.
3. Use discovery tools to periodically scan and identify changes to the host server OS, patches, and configuration settings.
Virtual Machine Provisioning
4. Maintain a version controlled library of build images in order to assure security and function.
5. Control library access so that check-in and check-out rights are based on role.
6. Use a tiered build approach to provision virtual machines, by having different images for OS level, middleware, application, then configuration settings, and have identified approved standard combinations of images.
7. * Test and verify build images work together so the virtual machines can be consistently rebuilt or re-provisioned after failure or to expand capacity.
Configuration Discovery and Tracking
8. Identify specific virtualized environment actions and changes that result in a CMDB update.
9. * Track software licenses during dynamic procedures (server, application, desktop) to ensure license compliance.
10. Update asset management practices to account for new virtualized capabilities.
Change Management
11. Document a rigorous change process that governs production virtual environments such as host, virtualized server, middleware, applications, and configurations.
12. Track frequent or common VM changes such as movement or capacity expansion within virtual machine cluster.
13. Virtualization tool actions trigger change record and discovery process (manual or automated) to verify details and update configuration records.
14. Enforce HR policies that require compliance with change controls, for example, following the change process is a condition of employment.
Failover and Disaster Recovery
15. Use virtualization to automate failover and rebuild processes so it is more repeatable.
16. Implement guidelines or policies on when to re-image or re-build in lieu of troubleshooting and repair.
17. Formalize criteria for targeting applications and servers on a common host.
18. Implement formal policy and procedures for managing virtual server failover, disaster recovery, or moving VMs within cluster for more resources.
Capacity and Performance Management
19. Actively monitor the capacity and performance of virtual machines so that resource constraints are identified and addressed.
20. Formalize virtual capacity and resource management policies.
Risk and Audit
21. Review the risk impact of virtualization as part of a standard enterprise risk management process.
22. Operations and audit review the risk impact of new virtual technologies.
23. Modify IT controls and procedures to address specific virtualization risks.
24. Update IT audit checklist to verify virtualization related controls.
Other
25. Modify procurement practices to pre-purchase resources (i.e. servers) previously purchased per project.

Figure 9 – List of 25 recommended high maturity static practices

Note – 57% % of high maturity organizations have or plan to a significant investment in virtualization training, as compared to an average of 34% baseline maturity organizations.[11]

Comments on recommended high maturity static practices

Host admin and access controls identified for high maturity organizations build on baseline recommended practices. In addition to defining host admin role, that role should be segregated from virtual machine admin. In addition to documenting host admin procedures, high maturity organizations should consider identifying host admin training requirements to further minimize single point of failure risk. In addition to defining host configuration requirements, high maturity organizations should follow a "trust but verify" tone at the top and use discovery tools to scan host resources for out-of-process changes. This "best practice" was previously noted as an ITPI recommendation for all organizations.

Various provisioning controls are also recommended for higher maturity organizations to extend recognized best practice to virtualized systems. High maturity groups in this study utilize a version controlled library of build images, and utilize roles based access to the library. Using a tiered build approach, so that different standardized images can be combined for provisioning and rebuild, provides an alternative to having to version control a single image. Using a single image that contains OS, middleware and applications, results in more frequent update of the image version due update and patch schedule of each component. These various images should be tested in production approved combinations.

There are various discovery practices that are recommended higher levels of production maturity that help manage a more dynamic environment. The high maturity group has the highest percentage of production assets assigned a unique ID or tracked in a configuration database. (67% average, compared to 58% for baseline maturity group).[12] High maturity organizations should identify specific virtual environment actions that trigger a CI and CMDB update. They should also update asset management practices and actively track and monitor software licenses to minimize risk of license compliance issues that are possible in a more dynamic virtualized environment.

Recommended change management practices also build on baseline maturity practices. The documented change process should be updated to explicitly address virtual system management. Rule and policy based movement of virtualized resources should be tracked to maintain accurate change audit trail. This includes failover and disaster recovery related events, as well as more frequent dynamic resource moves and capacity expansion within a cluster. To minimize impact on admin resource, virtualization tool triggers should be integrated with change tracking and discovery workflows to verify and document change history as an automated response to tool based action. Additional emphasis should be put on enforcing compliance with change policy to minimize virtual sprawl which is a greater risk in a more dynamic environment.

At higher levels of production maturity, virtualized failover and disaster recovery is formalized. Virtualization enables rapid failover and rebuild processes. Formal rules and policies and guidelines specify when systems should be reprovisioned or rebuilt in lieu of repair, and the movement of resources within clusters may be automated. Targeting criteria is formalized to determine which applications can be combined on specific hosts or clusters.

Capacity and performance management practices build on baseline recommendations. Host capacity and performance monitoring is extended to include all virtual machine resources, and resource management policies are defined.

In more mature implementations, use of production virtualization should be evaluated as part of a formal risk, governance and control process. Operations and audit should work together to modify existing controls and identify new IT controls that are needed to address risks associated with virtualization in production (using these recommended practices as a checklist). Audit and operations should also consider new controls that are now possible using virtualization such as more rigorous configuration standardization.

At higher level of maturity, organizations should also consider procurement practices to enable pre-purchase of computing resources, as a modification to typical procurement processes that are triggered by project funding.

Recommended practices – high maturity dynamic

We separated high maturity group into two different use cases to identify practices unique to those organizations using server virtualization to dynamic resource management objectives.

Organizations from the first high maturity use case labeled "High maturity static" use virtualization to meet high availability and disaster recovery objectives. They implement policies and rules to trigger activities as an exception to otherwise static deployment of OS consolidation. Response to policies and rules may be manually executed.

The Organizations from the second use case labeled "High maturity dynamic" implement policies and rules to trigger moving or adding resources not as an exception, but rather as a resource utilization and performance optimization strategy. Response to policies and rules is typically automated.

Figure 10 shows mix of server virtualization objectives that fit each use case.

High Maturity (172)	OS Consolidation	Dynamic Capacity	Failover DR
Dynamic (101)	X	X	X
	X	X	
		X	X
Static (71)	X		X
			X

Figure 10 - Two high maturity use cases based on server virtualization objectives

The difference in use of server virtualization practices in these two high maturity use cases are seen in Figure 11 which shows the percentage of practices used at level 4 or 5.

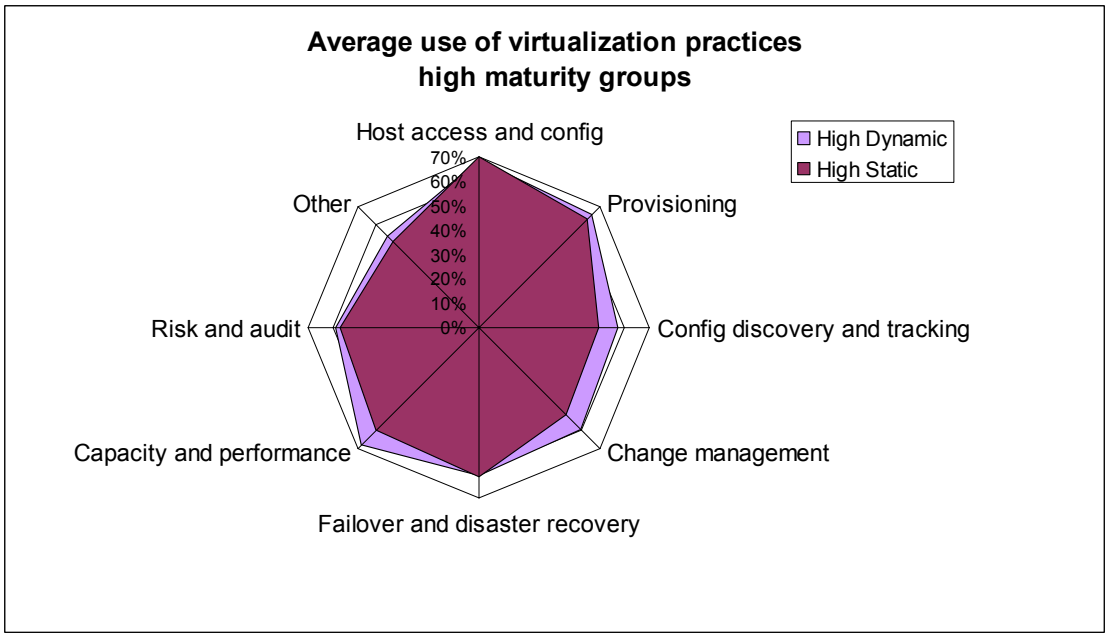


Figure 11- High maturity use cases with virtualization practices "In use"

Figure 11 indicates that there are differences in the frequency of use primarily in three areas of configuration discovery and tracking, change management, and capacity and performance.

Further statistical analysis revealed 12 practices in 5 areas that are in use at a higher frequency in the high maturity dynamic organizations, than the high maturity static group.[13] These recommended production dynamic practices, are listed seen in Figure 12. None of these practices in use at more than 70% of high maturity dynamic organizations.

Recommended High Maturity Dynamic Practices

Provisioning
1. Use a lifecycle tool to control the provisioning process and a staging environment to collect changes not yet released to golden image.
Configuration discovery and tracking
2. Increase the frequency of discovery or drift scanning in virtualized environments, as compared to non-virtual environments.
3. Modify discovery tools or capabilities to address issues related to scanning within virtualized environments.
4. Discovery tools and policies identify and track virtual machine cloning and moving within or between different clusters.
5. Follow policies on what virtualized components to track in CMDB – (i.e. host, virtual machine, cluster, desktop, application).
6. Integrate automation solutions with virtualization tools so that changes and actions result in some level of automated workflow to collect data and verify changes.
Change
7. Modify standard change categories or types to include virtual environment actions.
8. Add capacity and resource assessment to the standard change request evaluation criteria, for changes that impact virtual servers.
9. Expand list of pre-approved changes to include frequent or common virtual machine moves or capacity expansion.
Capacity and Performance
10. Performance management tools are virtual machine aware, and collect and consolidate data from the host, virtual machines, and applications.
11. Integrate performance management data for virtual capacity planning and management.
Other
12. Create a new virtualization team or role – specific to managing virtual environments.

Figure 12– List of 12 high maturity dynamic practices

Note – high maturity dynamic organizations are most likely to consider patch schedule when making host targeting decisions, which is an important consideration when identifying applications to include in a virtualized cluster. (38% of high maturity dynamic organizations consider patch schedule, as compared to 31% for all organizations.[14]

Whereas the high maturity static organizations are more likely to consider 1) failover and disaster recovery priorities (75% vs. 62% for all organizations) and 2) regulatory requirements (51% vs. 38%).

The top three targeting criteria for both baseline and high maturity groups combined include:

1. Uptime and availability SLAs (65% of organizations)
2. Failover and Disaster recovery priorities (62% of organizations)
3. Class of service (61% of organizations)

Comments on recommended high maturity dynamic practices

One provisioning practice is used at a higher level by high maturity dynamic organizations. They use a lifecycle tool that controls the provisioning process and create a staging environment to manage a queue of pending changes to approved images.

This group has several key discovery and tracking practices in use at a significantly higher level. Specifically, they increase the frequency of discovery and configuration drift tracking as compared to their use in non-virtualized environments. They also have modified discovery tools specifically to overcome the challenges of discovering virtualized assets. Discovery tools are able to identify virtual machine cloning and movement within and between clusters. They also expand CI tracking in a configuration database to specifically identify new virtualized environments such as clusters. They also have integrated automation solutions so that virtual environment changes initiate automated workflow to collect data and verify change records.

These organizations also extend the change management process to address dynamic environment changes. They expand the list of standard changes to include virtual environment actions. They add capacity and performance management evaluation as part of standard change approval process. And they expand the list of pre-approved changes to include expected virtual machine cloning and moves.

Capacity and performance management practices are also expanded. Performance and capacity management tools are "virtual aware" so that host, virtual machine, and application level data is consolidated and monitored. The integrated performance and capacity information is also used for virtual resource planning.

They also have created a new virtualization team or technical role, to specifically manage production virtual resources.

This set of recommended practices provides a set of recommendations that those organizations leveraging dynamic resource capabilities should consider for production environments.

Analyzing performance impact

The study was designed to assess level of use of various server virtualization practices, as well as their impact on a range of soft and hard performance measures.

Soft performance measures are used to identify key benefits of virtualization that are difficult to consistently measure across organizations via a web survey. For example, a hard measure for agility or speed of response to a business request is not consistently measured across organizations, and therefore difficult to collect in a survey.

Overall, we found that higher levels of production maturity do predict higher levels of performance in key areas of reduced sprawl and variance, increased use of automation, and reduced operational risk.

All three production groups score very high on the measure that indicates virtualization making production quality and service management efforts easier.

Those pursuing dynamic resource objectives had significantly higher performance in the areas of, increased speed and agility, fewer "war room" responses to service outages, and reduced audit effort.

We include hard datacenter operations measures related to change and release, resource utilization, service and support, and configuration control, since they are commonly used measures. We found a statistically significant correlation between recommended practices and hard measures.

- Baseline maturity group - host access controls predict variance in availability.
- High maturity static - provisioning automation and discovery practices predict variance in the release rollback rate. And capacity management practices predict variance in service support measures SLA fix rate, and mean time to repair large outages.
- High maturity dynamic - provisioning automation and configuration discovery practices predict variance in the percentage of production systems that match target configuration.

We also assessed various datacenter operating statistics to provide additional ways to profile different production maturity groups. These are not dependent variables, but rather offer profiling information that illustrates differences in operating environment related to different levels of production server virtualization maturity.

- High maturity groups show a higher rate of changes tested before release.
- High maturity groups also show higher rate of using a build library and automated provisioning.

Summary of soft measures

We tested a set of 10 soft measures with questions answered on a 1-5 scale. Figure 13 shows the percentage of organizations in each production group that answered at level 4 or 5 (5 indicating best performance). Response rates that are different at statistically significant level are shaded.

Soft Measures of virtualization impact in production	High Maturity Dynamic	High Maturity Static	Baseline Maturity
Sprawl and variance	(%)	(%)	(%)
1. Use of access, configuration and change policies has minimized virtualization server sprawl issues.	61	48	33
2. Virtual machine provisioning activities have improved the configuration consistency and reduced variance of production systems.	74	66	54
Agility and effort			
3. Virtualization has increased the speed in which the organization responds to production change requests that are managed through change tracking.	69	57	54
4. Overall, virtualization has made production quality and service management efforts easier.	69	73	70
5. Incidents require much fewer or fewer "war room" response	45	27	19
Automation			
6. Virtualization has resulted in increased use of process and procedure automation	72	54	41
7. Virtualization has improved or streamlined failover and rebuild process so that they are more repeatable and automated.	69	69	49
Risk and control			
8. Overall – virtualization has reduced datacenter management risk.	67	62	49
9. Significantly more systems are under failover and disaster recovery policy now that we have deployed virtualization.	64	58	33
10. Overall – our audit efforts have been reduced due to virtualization. (i.e. time spent pulling data on server configuration variance etc.).	61	51	38

Figure 13 - Summary of soft measures – production groups

Comments on performance variation – soft measures

Organizations in the two high maturity use cases scored higher measures that indicate procedures and controls minimize virtual sprawl, and virtual provisioning has helped minimize configuration variance. Those higher production maturity organizations have greater access, change and configuration control. Those in the baseline maturity group manage virtualization in a more static environment, and may not see the benefits associate with higher level maturity practices.

The high maturity dynamic organizations score higher in areas of speed of response, and reduced need for "war room" response to incidents. We assume that the higher maturity practices and more dynamic virtualization objectives help achieve these higher scores. Better rebuild, failover, or move of production systems as a response to failure should prevent war room efforts.

Interestingly, the all three production groups score very high on the measure that indicates virtualization making production quality and service management efforts easier. This is a strong result indicating an important benefit of production server virtualization. These findings offer a good proof point for those building bridges between server administrators and operations teams leveraging ITIL best practices.

Both of the high maturity groups measure higher level of use of automation, with the dynamic use case showing a significantly higher level of automation. This make sense as there is less need for automation for those pursuing only OS consolidation, and greatest need for automation in the high maturity dynamic use case.

Both high maturity groups show higher benefit from streamlined failover and rebuild processes. Note that the baseline maturity group, which is not aggressively pursuing production failover and disaster recovery virtualization objectives scores high as well. A closer look at the original segmentation reveals that 48% of the baseline maturity group that has aggressively pursued production consolidation has tentatively deployed failover and disaster recovery in production. An additional 28% of organizations in that group have an active evaluation or proof concept related to failover and disaster recovery objectives. They appear to be realizing benefit from these initial efforts.

Higher maturity groups indicate that virtualization reduces datacenter risk. The high levels of use of recommended high maturity practices correlates with reduced risk. 49% of the baseline maturity group also indicates that virtualization has reduced risk. This finding creates a strong proof point that virtualization, implemented with recommended practices, helps reduce risk operational risk.

The two high maturity groups have significantly more production systems under failover and disaster recovery control as a result of virtualization.

The high maturity dynamic organizations indicate that virtualization has reduced audit preparation efforts. This group also has the greatest use automation and tools that help create an audit trail of activities triggered by dynamic rules an policies.

Overall – higher maturity objectives and greater use of recommended server virtualization practices – correlates with wide higher scores on the full range of soft performance measures. All production groups score high marks virtualization improving ease of datacenter quality and service management efforts.

Summary of hard measures

We tested a set of 11 hard measures to study the impact of virtualization practices in this study. We analyzed the impact of the use of recommended practices for the baseline maturity group, and two high maturity use cases separately.

Figure 14 shows the hard performance measures for the baseline maturity group, and two production high maturity use cases. The 25th to 75th percentile range of answers are shown instead of average or mean answers for each group, to indicate the scores for the middle 50th percentile of responses. This "weeds out" the highest and lowest answers for each group which otherwise skew the measures.

25th to 75th percentile range	High Maturity Dynamic	High Maturity Static	Baseline Maturity
Resource Utilization			
1. Server/sys admin (all servers)	4 - 66	9 - 73	15 - 87
2. Server virtualization ratio	19 - 50	14 – 40	17 - 50
Change and Release			
3. Change success rate (%)	67 - 90	75 – 90	70 - 88
4. Emergency change rate (%)	5 – 25	5 – 23	5 - 20
5. Unauthorized change rate (%)	0 – 10	1 – 5	1 - 10
6. Release rollback rate (%)	2 – 10	2 – 10	3 - 10
Service and support			
7. Availability - downtime per month (min)	15 – 60	15 – 75	15 - 55
8. Outages fixed within SLAs (%)	56 – 95	75 – 96	65 - 95
9. MTTR serious incident (min)	120 – 360	90 – 270	90 - 305
Configuration control			
10. Servers match target configuration (%)	47 – 90	62 – 95	50 - 87
11. Security breaches auto-detect rate	50 – 98	75 – 99	10 - 95

Figure 14 – Summary of hard measures – production groups

Comments on performance variation – hard measures

Statistically significant group to group variations in measures include:

- Emergency change rate –the high maturity dynamic group has the highest rate
- Outages fixed within SLA, and mean time to repair (MTTR) large outages – high maturity static group has better measures, and
- Target configuration match rate, and security breaches auto-detected rate - high maturity static has highest measures.

Regression analysis reveals statistically significant correlation of practices to measures. Production dynamic use case has the strongest correlation. The use of provisioning automation and configuration discovery practices predict 23% of the variation in the rate at which servers match target configuration.

Production high maturity static use case has correlation in two areas. The use of provisioning automation and configuration discovery practices predict 6% of variation in the Release Rollback rate. And, the use of capacity management practices predict 6% of variation in Incident SLA fix rate, and 5% of the variation in Mean time to repair (MRRT) large outages.

Baseline maturity has correlation where the use of host access controls predict 6% of the variation in availability

Summary other operating statistics

Additional datacenter metrics help profile different production maturity groups. Figure 15 shows these metrics for baseline maturity, and two high maturity use cases. Response rates that are different at statistically significant level are shaded.

25th to 75th percentile range	High Maturity Dynamic	High Maturity Static	Baseline Maturity
1. Patch frequency - weekly/ biweekly/Monthly(%)	17/ 17/ 45	15/ 26/ 40	17/ 17/ 44
2. Incidents escalated to L2/L3 virtualization specialist (%)	5 – 22	5 – 20	3 - 20
3. Percent datacenter assets tracked in CMDB (%)	45 – 90	50 - 95	30 - 90
4. Planned maintenance (hours per week)	2 – 10	2 – 8	2 - 8
5. Changes tested before release (%)	75 – 99	75 – 99	67 - 90
6. Percent virtualized during HW refresh (%)	20 - 73	25 – 80	30 - 75
7. Production scan frequency (days)	5 – 30	5 – 30	6 - 30
8. Use build library for automated provisioning (avg)	51%	45%	31%

Figure 15- Summary of other operating data – production groups

Comments on performance variation – other operating stats

The three production groups have similar server patch schedules and planned maintenance hours each week, and similar production scanning frequency. They all track a similar percentage of datacenter assets with unique ID, and virtualize a similar percentage of server concurrent with a hardware refresh. And, they show a similar number of incidents escalated to virtualization specialists.

The primary differences in operating environment include:

1. High maturity groups show a higher rate of changes tested before release.
2. High maturity groups show higher rate of using a build library and automated provisioning.

Conclusions

The use of virtualization in production does change required operating procedures and controls in order to effectively manage operational risk. Those organizations with a strong foundation of process controls and best practices procedures such as ITIL, may only need to modify controls in a few areas to pursue consolidation objectives. However, pursuing higher maturity objectives requires consideration and implementation of additional procedures and controls.

Those pursuing higher maturity server virtualization objectives use more controls:

- Not yet in production – organizations not aggressively virtualizing production servers average 41% of the 51 tested practices in use.
- Baseline maturity – organizations aggressively consolidating production servers average 45% of tested practices in use.
- High maturity – organizations that have consolidated servers and are now pursuing high availability, disaster recovery, and dynamic resource objectives, average 69% of tested practices in use.

Based on 15 executive interviews, and analysis of data collected data from 323 IT organizations, we identified three sets of recommended practices:

- **Baseline maturity practices** – 11 practices recommended for those organizations consolidating servers and virtualizing business critical systems in the production environment. Focus improvements in the areas of host access and configuration controls, virtual machine provisioning, and capacity and performance management.
- **High maturity static practices** – 25 recommended practices for those organizations expanding beyond server consolidation to high availability and disaster recovery objectives in an otherwise static environment. Focus improvements on quickly responding to performance impacting conditions with a high degree of configuration standardization, provisioning with approved build images, and using a "trust but verify" strategy for change process and configuration compliance.
- **High maturity dynamic practices** – 12 recommended practices for those organizations pursuing dynamic resource management objectives. Incremental controls primarily in the area of configuration discovery and tracking, change approval, capacity management, and overall process maturity needed to support automation.

Those responsible for datacenter operations and performance should consider these lists of recommended practices that match their current and future production server virtualization objectives.

IT Audit can use these lists to evaluate the impact of production virtualization on audit checklist, as part a governance risk and compliance review process.

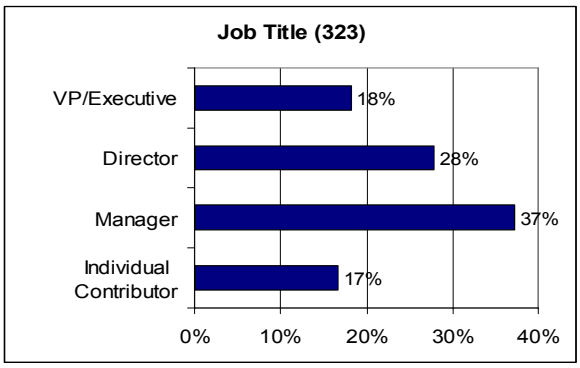
Appendix A – glossary

- **Baseline maturity** – those organizations focused on OS consolidation.
- **Baseline maturity practices** – practices recommended for organizations pursuing OS consolidation.
- **Business critical** - production systems that have highest strategic value to the organization. The availability of these production systems is critical for enabling key business processes or customer facing systems. Outage of these systems has highest priority over outage of other non-critical systems.
- **High maturity** – organizations that have virtualization objectives beyond OS consolidation, including both high maturity static and high maturity dynamic.
- **High maturity dynamic** – organizations that use virtualization to implement policies and rules to trigger moving or adding resources not as an exception, but rather as a resource utilization and performance optimization strategy. Response to policies and rules is typically automated.
- **High maturity dynamic practices** - recommended practices for organizations who are pursuing production virtualization objectives related to dynamic resource management.
- **High maturity static** – organizations that use virtualization to meet high availability and disaster recovery objectives. They implement policies and rules to trigger activities as an exception to otherwise static deployment of OS consolidation. Response to policies and rules may be manually executed.
- **High maturity static practices** – recommended practices for organizations who are pursuing production virtualization objectives beyond OS consolidation.
- **Maturity** – related to the level of use of virtualization practices. We found correlation between objective and maturity. Those pursing only OS consolidation objective measure lower use of virtualization practices.
- **Not yet in production** – many IT organizations are using virtualization, but not in the production environment. Virtualization may be used for test and development environments.
- **Production** – Servers that are not test and development. These might be considered "Tier 1" systems. Not all production systems are business critical. We differentiate business critical as production systems that have highest strategic value to the organization.
- **Virtualization Objective** – what the IT organization is trying to accomplish by virtualizing production servers. This study highlights three primary objectives 1) OS consolidation, 2) high availability and/or disaster recovery, and 3) dynamic resource allocation.

Appendix B - study demographics

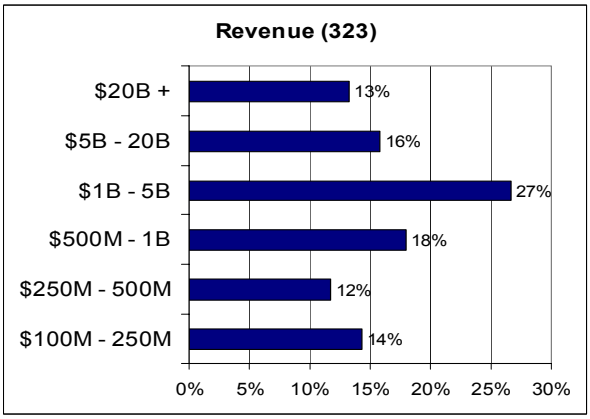
Data was collected from 323 IT organizations by custom research firm HANSA/GCR. They deployed a web-based survey based on finding from 15 executive interviews, and managed data collection in October 2008. The survey respondents were invited from HANSA/GCR North American IT executive interview panels.

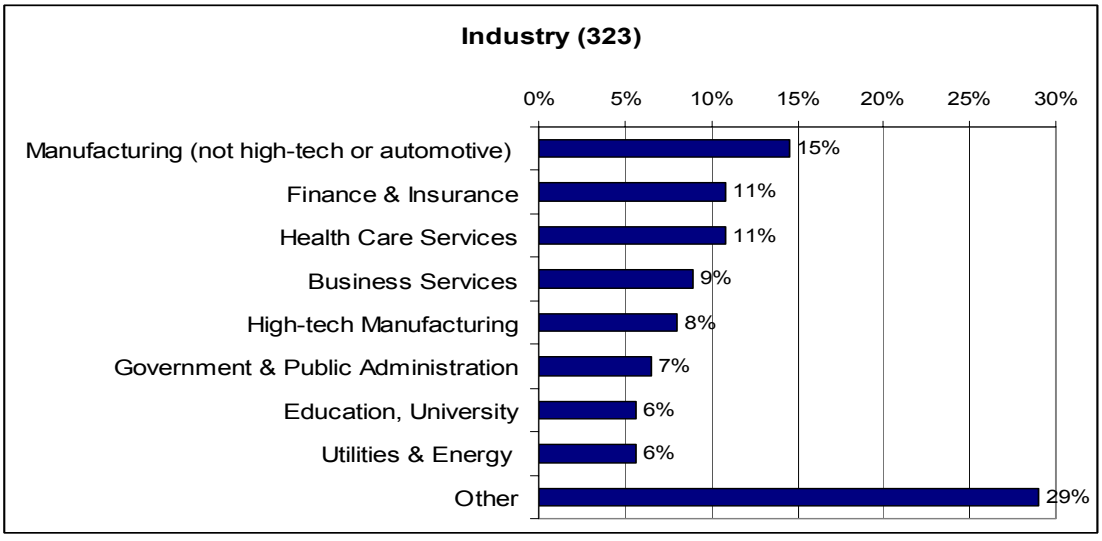
46% of survey respondents are, IT Executive, Vice President or Director level job titles.



A broad range of company revenues (or operating budgets if public agency) are represented:

- 26% less than $500M
- 18% between $500M and $1B
- 27% $1B and $5B
- 29% from companies with revenue >$5B.





Appendix C - notes on study methodology

Industry Sample

Our screening questions were designed to select participants with a high level of expertise and knowledge about their organization's use of virtualization.[15] The study is not designed to provide a representative sample of overall industry population or overall use of virtualization.

As a result, the data may over represent those organizations pursuing higher maturity objectives. However, the sample does include a good mix of organizations with different production virtualization objectives, which allows comparative analysis of their use of procedures and controls.

Correlation with performance

In previous ITPI studies that correlate practice to performance, the practices and performance measures apply broadly to the production environment. For example change controls apply to all systems in production. As a result, the impact of those practices can be measured using datacenter-wide metrics such as change success rate.

In this study, not all production systems are virtualized. However we ask performance measure questions that apply all production systems. This might mask the performance improvement potential of the practices, and reduce the performance improvement measured across organizations. A better approach would be to ask about performance improvement using before and after snapshots, for just the systems that are virtualized.

In other cases, we have identified issues with question wording. We would expect to see more mature organizations measure higher virtualization ratios, and higher server to system administer ratios. However, VMware survey developers indicate that the question wording is not clear. The survey questions should use terms "dedicated", "host", and "guest" server, instead of "physical" and "virtual" servers. The wording may have confused survey respondents leading to ambiguous data.

Selection Bias

Those with highest maturity use of virtualization practices were most likely to be individual contributors responsible for virtualization technical decisions. Higher levels of technical expertise may bias answers for high maturity groups.
See endnote 15.

End notes

[1] Answer to question – "We have or at one point had a limited release of virtualization (i.e. limited rollout) until we increased training and identified specific virtualization management procedures."

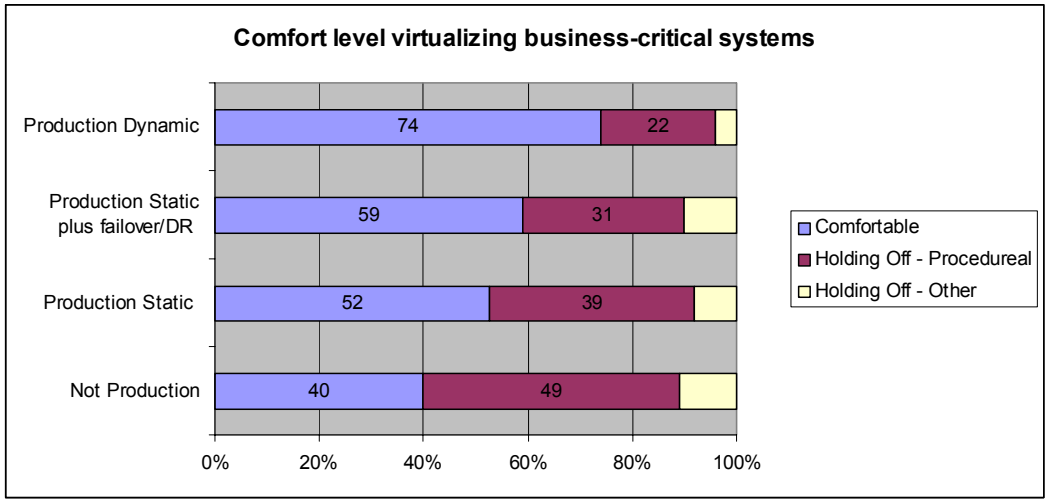
58% of high maturity organizations answered 4 or 5 on a 5 point scale, indicating strong agreement with the statement. Only 43% of baseline maturity organizations answered 4 or 5, indicating that high maturity organizations exhibited greater caution prior to widespread adoption.

[2] Answer to question – "Overall, is your organization comfortable with your maturity of access, change, and configuration controls, and administrative training -- that allows you to aggressively pursue virtualization of business critical systems?"

1. Comfortable: We are aggressively pursuing virtualization for our most business-critical systems, and are comfortable with controls, procedures, and skills.
2. Holding of procedural concerns - We are holding off putting our most business critical systems in virtualization environment until we identify and implement optimal virtualization related policies, procedures, controls and skills.
3. Holding off other concerns - We are holding off putting our most business critical systems in virtualized environment for other reasons.

64% of organizations aggressively pursuing production virtualization are comfortable virtualizing business critical systems.

Table shows answers for four use case groups in the study



Top three reasons cited for "holding off – other" include:

1. application performance
2. operational priority
3. budget.

[3] Answer to question – "Do any of your virtualized systems contain data or applications that are in scope for IT audit in order to comply with external regulations such as Sarbanes-Oxley, HIPPA, PCI security, or government security mandates?"

1- Yes, some or all virtualized environments and related IT operating practices are in scope for regulatory compliance.
2- No, we have not virtualized business systems that are in scope for external regulations.

68% of organizations aggressively pursuing production virtualization answered "yes".

[4] Fall 2008 customer study "VMware Infrastructure Adoption Trends". 1038 total respondents. Top three answers to question "What are the top three objectives you seek for data center virtualization in your company this year? (select up to three)". Four most frequent answers include:

1. Use virtualization to improve business continuity and disaster recovery – 45%
2. Increase server consolidation ratio – 40%
3. Improve virtual machine performance - 30%
4. Improve management of VM environment – 30%

[5] We identified the percentage of organizations in each group that scored the 1 or 2 on 1-5 scale. We used a T-test at 95% confidence level to identify individual practices that the non-production group had high frequency of scored at levels 1 or 2, as compared to other groups. We also identified the percentage of organizations in each group that scored 4 or 5 on 1-5 scale. We identified practices where baseline maturity and high maturity groups had 50% or more answered at level 4 or 5.

[6] Answers to question - "Have you virtualized a single server platform (i.e. Intel/Microsoft Windows) or multiple platforms that require different performance management and virtualization tools?"

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Multi-Platform	34%	46%	49%

[7] Answers to question – "We patch and update the virtualization host using tools other than those provided by the virtualization tool vendor. (i.e. a 3rd party tool)." Answered at level 4 or 5.

- Production – 61%
- Non-production – 38%

[8] *Leveraging IT controls to improve operating performance*. 2008. Funded by Institute of Internal Auditor Research Foundation. Identified 12 foundational controls that if implemented at sufficient process maturity level, had statistically significant impact on a range of IT operating measures.

Change Configuration and Release performance study. 2008 IT Process Institute. Identified various sets of controls that have statistically significant impact on related performance measures.

[9] Center for Internet Security. ESX hardening guidelines. http://www.cisecurity.org/bench_vm.html

[10] We identified the percentage of organizations in the baseline and high maturity groups that scored 1 or 2 on 1 to 5 scale. We used a T-test at 95% confidence level, to identify individual practices that the baseline maturity group had high frequency of scores at level 1 or 2. We also identified the percentage of organizations in each group that scored 4 or 5 on 1 to 5 scale. We identified practices where less than 50% of baseline maturity group scored 4 or 5, and more than 50% of the high maturity groups answered at level 4 or 5.

[11] Answers to question - "We have made or plan to make a significant investment in training virtualization related personnel."

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Training Investment	34%	57%	56%

[12] Answer to question – "What percentage of total datacenter assets (physical and virtual) have unique ID or are tracked in CDMB or other tracking system that includes configuration details?"

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Average percent datacenter assets with unique ID or tracked in CMDB (%)	59%	71%	64%

[13] We identified the percentage of organizations in each group that scored 4 or 5 on 1-5 scale. We identified practices where more than 50% of the high maturity dynamic use case groups answered at 4 or 5 level, and less than 50% of baseline maturity and high maturity groups scored 4 or 5.

[14] Answers to question – "What criteria is considered when targeting applications and server for consolidation onto a common host? Multiple responses allowed."

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Uptime or availability SLAs	61%	69%	72%
Failover/DR priorities	59%	75%	64%
Class of service	72%	65%	58%
Maintenance windows	56%	49%	54%
Business unit or app. owner	41%	39%	48%
Regulatory Requirements	28%	51%	38%
Patch schedule	33%	34%	38%

[15] Survey respondent screening - 100% of respondents indicated that they were "Knowledgeable about management and support of virtualization solutions at my organization".

Of those, 50% indicate they are also responsible for making technical decisions about virtualization. The percent responsible for technical decisions for maturity groups include:

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Responsible for Technical Decisions	51%	44%	68%

In addition, individual contributors were more likely to represent high maturity organizations.

	OS Consolidation	Failover or Disaster Recovery	Dynamic Capacity
Individual Contributor	3%	23%	21%

Potential bias in survey – those with highest maturity use of virtualization practices were most likely to be individual contributors responsible for virtualization technical decisions. This technical expertise may bias answers for high maturity groups.