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Management Report

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Value of Database Resilience

Comparing Costs of Downtime for IBM DB2 10.5 and Microsoft SQL Server 2014

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Executive Summary

The Players

The database world is undergoing unprecedented change. Data growth continues to accelerate. Database structures are becoming more complex. New interoperability and performance challenges must be met as use of NoSQL and unstructured data gain traction. Cloud computing defines new deployment and operating models. Escalating demands for information place new stresses on database infrastructures.

These shifts have changed the strategies of the major database vendors. IBM and Microsoft, which are the focus of this report, have added new technologies to their mainstream DB2 and SQL Server platforms.

In analytics, the primary competition is between DB2 BLU Acceleration, a new subsystem in IBM DB2 10.5 introduced in June 2013; and Microsoft Clustered Columnstore Indexes, first implemented in SQL Server 2008 R2. Both employ columnar data structures, in-memory processing and other advanced technologies to accelerate throughput for high-volume analytical workloads.

DB2 and SQL Server also, however, continue to compete in transaction processing. There is a steady momentum of new deployments and legacy replacements in enterprise resource planning (ERP) and other business-critical systems. Transactional e-commerce solutions have seen even higher growth levels, while an ever-larger segment of the cloud service provider industry supports transaction-processing workloads.

In this area, the competition is currently between DB2 10.5 and Microsoft SQL Server 2014, which was introduced in June 2013 and became generally available in April 2014.

SQL Server has been widely deployed for transactional applications. Systems have, however, typically been smaller, and workloads less availability- and recovery-sensitive than for DB2. In comparison, DB2 handles some of the world's largest transactional systems with industry-leading levels of availability and recoverability.

The general industry perception has been that, while recent versions of SQL Server may be appropriate for low- to mid-volume workloads, it is not competitive with databases such as DB2 and Oracle for large-scale systems. According to Microsoft, the introduction of the In-Memory OLTP feature in SQL Server 2014 significantly changes the competitive picture. It remains to be seen whether this is the case.

SQL Server 2014 continues to suffer from scalability limitations for high-end transactional workloads. Performance is, moreover, heavily application- and workload-dependent, key capabilities are still immature, and in-memory technology is vulnerable to memory bottlenecks that may cause outages and delay recovery. In addition, the In-Memory OLTP feature is poorly integrated with the overall SQL Server 2014 environment.

For business-critical systems, these are obvious negatives. Mainstream production use of this feature would, for most organizations, be a high-risk proposition.

Availability and Recoverability

Both vendors offer high availability clustering solutions. IBM DB2 pureScale for clustered failover and High Availability Disaster Recovery (HADR) for disaster recovery, however, offer significantly higher scalability and reliability than the Microsoft equivalent, AlwaysOn Availability Groups.

Users of the IBM solution set have routinely achieved mainframe-class availability and recoverability even for very large, volatile transaction processing workloads.

AlwaysOn mirroring and recovery functions have proved attractive to many SQL Server users. However, downtime levels are typically higher than for DB2 for comparable applications, and recovery is a longer, less efficient process. AlwaysOn Availability Groups approximate IBM HADR. There is no Microsoft equivalent to DB2 pureScale.

The implications are important. The impact of downtime for core business systems in financial services, retail and other industries has been widely documented. Decades of experiences in e-commerce have also shown that major system outages may result not only in immediate lost sales, but also in lost future business and long-term erosion of customer loyalty.

Cloud computing is also proving to be vulnerable. Customers are increasingly sensitive to risks that providers will not be able to maintain adequate availability. Outages may result in customer attrition, revenue loss and potential legal exposure. High-profile events may deter new customers.

These effects are a function not only of unplanned (i.e., accidental) outages, but also of planned downtime for such tasks as upgrades and preventative maintenance. Globalization, escalating competition and use of the Internet mean that businesses are increasingly operating on a 24/7 basis. Maintenance windows are disappearing.

The ability of DB2 10.5 to deliver higher levels of availability results in significantly lower *costs of downtime*. This may be illustrated by comparisons of three-year costs for business-critical transaction processing system installations in financial services, manufacturing and cloud services companies that are summarized in figure 1.

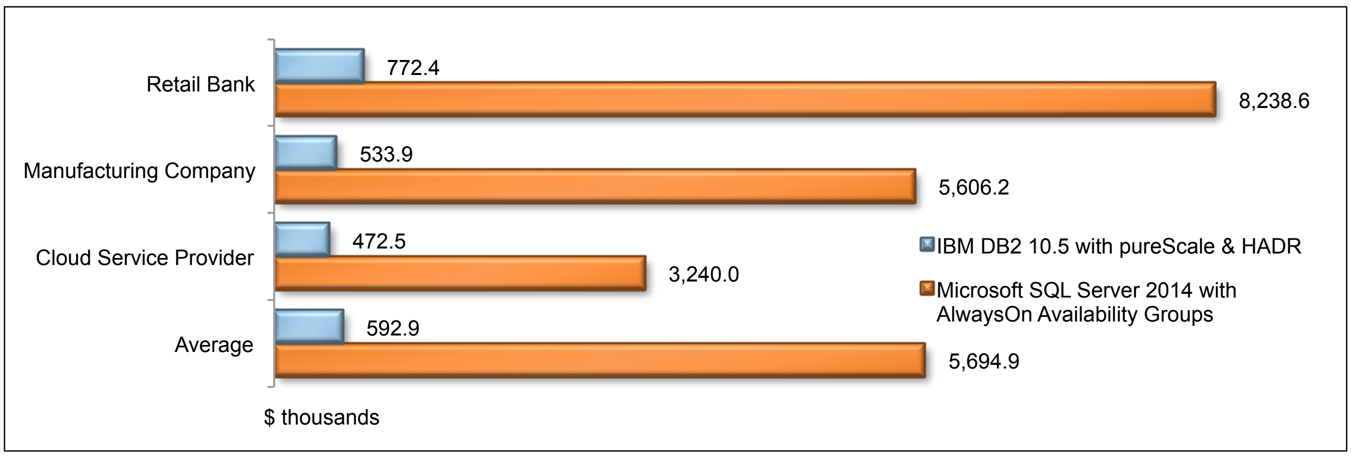

Figure 1: *Three-year Costs of Downtime for Business-critical Transaction Processing Systems*

For the financial services company, calculations allow for lost income due to customer attrition, lost cross-sell and upsell opportunities, and lost customer acquisition costs. For the manufacturing company, costs are for disruption of procurement, production and logistics operations, along with customer late fees and imperfect order penalties. Cloud service provider costs include lost income and rebates.

DB2 10.5 recovery from outages is – by wide margins – faster and more effective than for use of SQL Server with AlwaysOn Availability Groups. In the same three companies, use of DB2 10.5 results in *severe outage costs* that average 97 percent less. Figure 2 illustrates disparities.

Severe outage costs included the same components as for costs of downtime calculations, although values are significantly higher. Allowance was also made for administrative, marketing, public relations and, in the case of the financial services company, legal and regulatory costs.

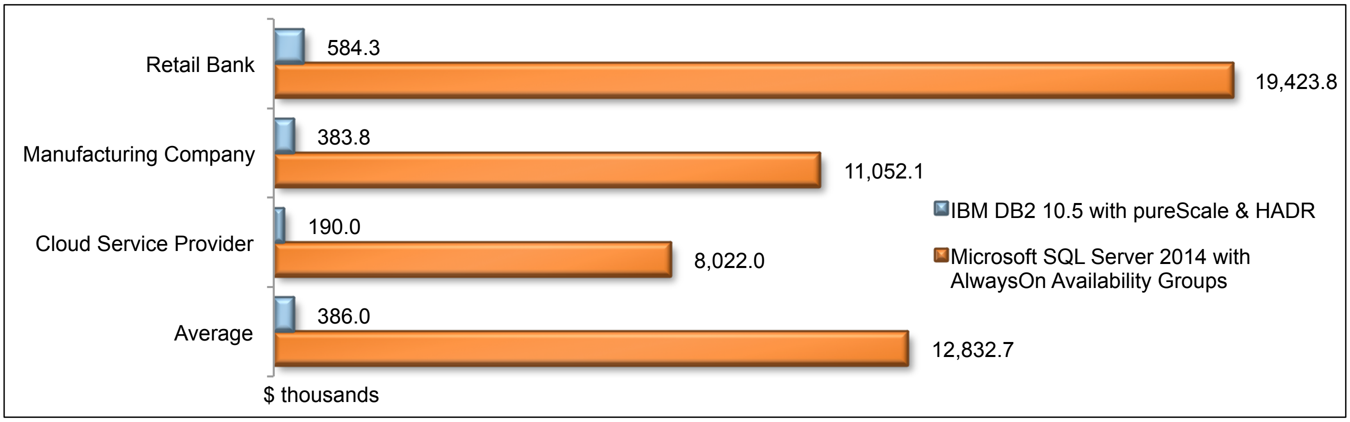

Figure 2: *Severe Outage Costs for Business-critical Transaction Processing Systems*

Calculations for costs of downtime and severe outage costs are based on input from 36 companies in the same industries that employed DB2 10.5 or Microsoft SQL Server 2012 and/or 2014 for comparable applications. Companies were approximately the same size, with generally similar business models.

Availability and recoverability have also become critical competitive issues for cloud service providers. Publicly traded companies, for example, have reported the risk factors cited in figure 3.

Defects or disruptions in our service could diminish demand for our service & subject us to substantial liability.

Our service may have errors or defects that could result in unanticipated downtime for our subscribers. Since our customers use our service for important aspects of their business, any errors, defects, disruptions in service or other performance problems could hurt our reputation & may damage our customers' businesses.

As a result, customers could elect to not renew, or delay or withhold payment to us, we could lose future sales or customers may make warranty or other claims against us, which could result in an increase in our provision for doubtful accounts, an increase in collection cycles for accounts receivable or the expense & risk of litigation.

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Any errors, defects, disruptions or other performance problems with our services could harm our reputation & may damage our customers' businesses.

Interruptions in our services might reduce our revenue, cause us to issue credits to customers, subject us to potential liability, cause customers to terminate their subscriptions & harm our renewal rates. We may become liable to our customers & lose customers if we have defects or disruptions in our service or if we provide poor service.

If we have any errors, defects, disruptions in service or other performance problems with our suite, customers could elect not to renew, or delay or withhold payment to us, we could lose future sales or customers may make warranty claims against us, which could result in an increase in our provision for doubtful accounts, an increase in collection cycles for accounts receivable or costly litigation.

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We provide service-level commitments to our customers, which could cause us to issue credits for future services if the stated service levels are not met for a given period & could significantly harm our revenue.

If we are unable to meet stated service-level commitments or suffer extended periods of unavailability for our service, we may be contractually obligated to provide these customers with credits for future services. Our revenue could be significantly impacted.

Failure to meet (our) service-level commitment may require us to credit qualifying customers for the value of an entire month of their subscription fees, not just for the period of downtime. As a result, a failure to deliver services for a relatively short duration could cause us to issue these credits to all qualifying customers. Any extended service outages could harm our reputation, revenue & operating results.

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Customers with mission-critical applications could potentially expose us to lawsuits for their lost profits or damages.

Because our services are critical to many of our customers' businesses, any significant disruption in our services could (cause them) lost profits or other consequential damages. Although our agreements attempt to limit our liability for service outages, we cannot be assured that a court would enforce any contractual limitations on our liability in the event that one of our customers brings a lawsuit against us.

The outcome of any such lawsuit would depend on the specific facts of the case & any legal & policy considerations that we may not be able to mitigate. In such cases, we could be liable for substantial damage awards that may exceed our liability insurance coverage.

Figure 3: *Risk Factors Cited by Cloud Service Providers: Examples from Recent Annual Reports*

Other Differences

There are also significant differences between DB2 10.5 and SQL Server 2014 in other areas.

Non-columnar *data compression* technology in DB2 10.5 is functionally broader, addresses a wider range of data structures, and enables higher compression levels than is the case for SQL Server 2014. Greater savings may be realized in storage hardware, in license and support fees for software priced on a per terabyte (TB) basis, in backup systems and media, and in data center energy and occupancy costs.

Mainframe-derived *workload management* facilities in DB2 10.5 are more granular and better optimized for transactional workloads than SQL Server 2014 Resource Governor. Resource Governor is a great deal less mature, and is typically employed to support smaller, less business-critical workloads than DB2 10.5.

DB2 10.5 benefits from simpler task structures and higher levels of *automation* that result in faster process execution and lower levels of full time equivalent (FTE) staffing for a wide range of database administrator (DBA) and, in some cases, system and storage administration tasks. Databases and clusters integrate distinctive IBM autonomic technologies for which there are no SQL Server 2014 equivalents.

In terms of *cloud* functionality, SQL Server 2014 is differentiated by its ability to interface to Microsoft's proprietary Azure solutions and services. In comparison, DB2 10.5 is used with a variety of third-party cloud services. It may also, unlike SQL Server 2014, be deployed on Linux and UNIX as well as Windows servers.

A new DB2 10.5 feature introduced in August 2014 allows concurrent processing of queries and transactions. Users may create columnar *shadow tables* of row-based transactional data, and execute queries directly on these in a manner that exploits the full capabilities of DB2 BLU Acceleration in-memory technology. Transactional data is continuously and automatically replicated to shadow tables.

Early adopters have typically employed this capability for real-time operational queries and reporting. Users report that DBA overheads are minimal, and that there is no impact on transactional performance. There is no SQL Server 2014 equivalent.

Conclusions: Business-criticality

Maintaining high levels of uptime and recoverability is difficult process under any conditions. As database sizes and transaction volumes expand, however, challenges escalate – in a manner that is closer to exponential than arithmetic. They expand further when mixed processes and experience wide, unpredictable fluctuations characterize workloads.

The challenges of supporting transactional workloads are, moreover, significantly different from those for messaging, collaborative, light-duty database query and reporting, and other workloads for which SQL Server clustering is commonly employed. Large-scale transaction processing systems are a great deal more exacting.

Cloud computing, by driving consolidation of infrastructures within and across organizations, is pushing large segments of the IT industry toward business-critical models. Escalating competition among cloud solution and server providers will oblige many to differentiate by offering service levels that resemble the traditional mainframe world.

Similar pressures extend to social media. Networks for peer-to-peer interaction, collaboration and gaming increasingly support global user communities. Service providers have found that 24/365 availability is mandated. Acceptable maintenance windows no longer exist. Any outage may impact millions of users.

For many users, the demographic advantages of employing SQL Server remain compelling. Skill bases, applications and tools, and third-party support are easily available. But if current trends are projected into the future, it is clear that demands for business-critical capability will become pervasive. The idea that it is sufficient to deliver 99.5 percent, or even 99.9 percent availability may become a historical curiosity.

Availability and Recovery

General Trends

Availability and recovery solutions have a long history in the IT industry. Recent trends, however, have caused their use to become increasingly widespread.

Such solutions have long been the norm for *conventional business-critical systems*. Examples include enterprise resource planning (ERP) systems; core banking systems; reservation systems in travel and hospitality; merchandising systems in retailing; customer information systems in telecommunications and utilities; policy management and claims processing systems in insurance; patient care systems in health care; and comparable systems in other industries.

In such environments, any interruption of service may have significant bottom-line impacts that range from idle or underutilized capacity to customer late fees and imperfect order penalties. If the experience is repeated, customers may be lost.

Vulnerabilities have been magnified by adoption of *lean* models that minimize inventories, and by streamlining and acceleration of a wide range of processes. Since the mid-2000s, researchers have documented *cascading* effects in hundreds of companies in manufacturing, retail, distribution, transportation and other industries.

In supply chains operating in real time, with few or no inventory buffers, delays in one process can rapidly affect others, and may spread across the entire supply chain. For example, a delay in delivering parts to a plant may cause finished product shipment deadlines to be missed. This may affect transportation schedules and distribution operations. The impact is cumulative.

E-commerce businesses have learned similar lessons. In online retailing, for example, 24/365 usage has become the norm, and even short outages during off-peak periods may cause significant losses. If protracted outages occur at times of high usage (e.g., during seasonal sales peaks, or in response to new product launches, promotions or Internet buzz), losses may be massive.

Industry Effects

It has become a truism that, in online retailing, *customers are only a few clicks away from competitors*. Shoppers who divert to another supplier because they are unable to research a product, determine availability or place an order may not return. Even if they do, they are more likely to buy from multiple sources in the future.

Similar effects have been documented in other industries. In *financial services*, for example, it has long been known that outages affecting conventional systems may translate into immediate lost income (e.g., ATM, credit and debit card fees). Over time, however, it has become clear that downtime for any customer-facing system may cause serious bottom-line damage.

A customer who cannot obtain balances, place queries, pay bills or perform other account actions because a system is down will inevitably be dissatisfied. Even if the immediate impact cannot be easily quantified, it will show up in customer attrition statistics. In developed economies, average bank income per retail customer routinely exceeds $1,000 per year.

Allowance should also be made for lost customer acquisition costs. In developed countries, these are routinely $200 to $400 per customer. This expenditure is inevitably lost if a customer defects.

Effects are magnified if losses are measured in terms of customer lifetime value (CLV) and equivalent metrics. The effects of protracted outages may be a great deal more serious.

In June 2012, for example, the U.K-based *Royal Bank of Scotland (RBS)* experienced a four-day outage affecting all branch systems, ATMs, debit and credit cards, online and mobile banking and call center operations. All channels and customer touch points were affected.

The outage left 17 million of the company's 23 million customers unable to access account information, withdraw or transfer funds, or process payments for up to six days. Media coverage was massive and entirely negative. Political and regulatory intervention rapidly followed.

RBS spent over $300 million on customer reimbursements, overdraft extensions and other remedial actions, which included extending hours at more than 1,200 out of 2,500 branches and doubling call center staff to deal with a flood of customer queries. The final cost to the company is believed to have been over $500 million.

The extent of customer attrition is unclear, although it is believed to run to millions of individuals. The impact was magnified by further core system outages in March and December 2013.

There has been growing awareness of the potential impact of such incidents. Risk factors cited by publicly traded financial services and manufacturing companies, for example, are presented in figures 4 and 5.

***We depend on information systems to conduct our business & could suffer a material adverse impact from interruptions in the effective operation of those systems*.**

We handle a substantial volume of customer & other financial transactions virtually on a continuous basis… Our systems could fail to operate as needed due to factors such as design or performance issues, human error, unexpected transaction volumes, or inadequate measures to protect against unauthorized access. All of these types of events could disrupt our ability to use our accounting, deposit, loan & other systems & could cause errors in transactions with customers, vendors or other counterparties.

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Technology & operational failures or errors could subject the Company to losses, litigation & regulatory actions.

It could take several hours or more to restore full functionality to the Company's technology systems in the event of an unforeseen event (affecting) the Company's ability to process client transactions. (Such an event) might also negatively impact the Company's reputation & client confidence in the Company, in addition to any direct losses that might result from such instances. Disruptions in service could result in substantial losses & decreased client satisfaction.

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Our information systems may experience an interruption.

We rely heavily on communications, information systems & the Internet to conduct our business. Our business is dependent on our ability to process & monitor large numbers of daily transactions in compliance with legal, regulatory & internal standards & specifications.

In addition, a significant portion of our operations relies heavily on the secure processing, storage & transmission of personal & confidential information, such as the personal information of our customers & clients. In the event of a failure, interruption or breach of our information systems, we may be unable to avoid impact to our customers.

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Operational difficulties, failure of technology or information security incidents could adversely affect business & operations.

Any failure, interruption or breach in security of (key) systems could result in failures or disruptions in customer relationship management, general ledger, deposit, loan & other systems.

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Our information systems may experience an interruption or security breach.

We rely heavily on communications & information systems to conduct our business. Any failure, interruption or breach in security of these systems could result in failures or disruptions in our customer relationship management, general ledger, deposit, loan & other systems, misappropriation of funds, & theft of proprietary company or customer data.

The occurrence of any failure, interruption or security breach of our information systems could damage our reputation, result in a loss of customer business, subject us to additional regulatory scrutiny, or expose us to civil litigation & possible financial liability.

Figure 4: *Risk Factors Cited by Financial Services Companies – Recent Examples*

Failure of key information systems could adversely impact the Company's ability to conduct business.

The Company relies extensively on information technology systems in order to conduct its business. If systems are damaged or cease to function properly, & if business continuity plans do not effectively resolve such issues on a timely basis, the Company may suffer interruptions in the ability to manage or conduct business that may adversely impact the Company's business.

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Our operations are highly dependent on information technology & failures could significantly affect our business.

We depend heavily on our information technology infrastructure in order to achieve our business objectives. If we experience a problem that impairs this infrastructure, such as…a problem with the functioning of an important IT application, or an intentional disruption of our IT systems by a third party, the result could be to impede our ability to record or process orders, manufacture & ship in a timely manner, or otherwise carry on our business.

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A substantial interruption in our information systems could have a material adverse effect on our business.

We depend on the security & integrity of electronic data & our management information systems for many aspects of our business. We may be materially adversely affected if our management information systems are disrupted or compromised or we are unable to improve, upgrade, maintain & expand (them).

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Any material disruption of our information systems could disrupt our business & reduce our sales.

We may experience operational problems with our information systems. Any material disruption or slowdown of our systems could cause information to be lost or delayed which could—especially if the disruption or slowdown occurred during the holiday season—result in delays in the delivery of merchandise to our stores & customers or lost sales, which could reduce demand for our merchandise & cause our sales to decline.

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Any significant interruption in the operations of our customer call, order fulfillment & distribution facilities could disrupt our ability to process customer orders & to deliver our merchandise in a timely manner.

Any significant interruption in the operation of these facilities, including an interruption caused by our failure to successfully expand or upgrade our systems or manage our transition to utilizing the expansions or upgrades, could reduce our ability to receive & process orders & provide products & services to our stores & customers, which could result in lost sales, cancelled sales & a loss of loyalty to our brand.

Figure 5: *Risk Factors Cited by Manufacturing Companies – Recent Examples*

Numerous examples could be cited in other industries, and in government and nonprofit organizations.

DB2 10.5

DB2 pureScale

Introduced in 2009 for DB2 for Linux, UNIX and Windows (DB2 for LUW), DB2 pureScale is a shared disk failover cluster solution that is designed to support high-volume, business-critical transaction processing systems. It can be configured with up to 128 nodes, and typically completes failover in a matter of seconds.

The scalability of this solution means that, in the event a node shuts down or must be taken offline, the impact on production is minimized. In a 16-node cluster, for example, loss of a node means that performance is reduced by only around six percent. In a two-node cluster, it is reduced by 50 percent.

Other benefits include the following:

- Nodes can be added to DB2 pureScale clusters in a non-disruptive manner. Increases in cluster size to handle workload growth and/or improve redundancy do not affect running applications.

  System maintenance and software upgrades may also be performed without downtime. DBAs can perform rolling updates; i.e., nodes may be serviced or upgraded sequentially, or groups of nodes may be updated in parallel. The amount of DBA time required may be minimized.

- Applications are transparent to the underlying cluster, and do not need to know numbers of nodes, which are active or inactive, or where data is placed. Application development processes are greatly simplified.

DB2 pureScale supports InfiniBand interconnects or (since August 2014) standard TCP/IP sockets. TCP/IP sockets offer greater cost-effectiveness; e.g., in smaller clusters, or in lower-volume environments.

IBM licensing allows organizations to pay only for used capacity within clusters. This has proved particularly valuable to users that experience significant fluctuations in workloads over time.

DB2 pureScale is based on *IBM Parallel Sysplex Data Sharing*, which has supported the world's largest mainframe-based transactional systems, in some cases for more than 20 years. Deployed by more than 400 organizations, it is generally recognized to be the most scalable and reliable clustering solution available today.

Production Parallel Sysplex Data Sharing clusters routinely run from 2 to 10 nodes, and many are in the 10- to 20-node range. DB2 pureScale incorporates the overall design, along with distributed locking, cache management and other mechanisms derived from this architecture.

A key component of Parallel Sysplex Data Sharing and DB2 pureScale is the Cluster Caching Facility (CF), whose operation is illustrated in figure 6.

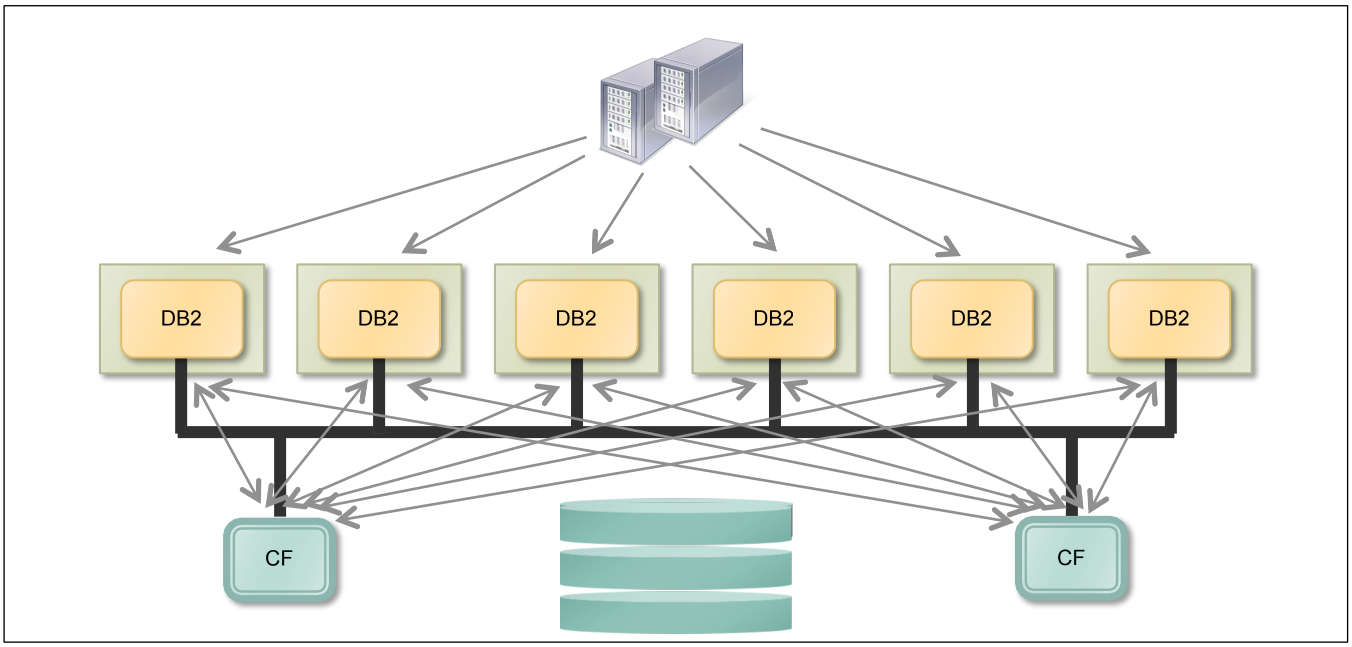

Figure 6: *IBM DB2 pureScale Cluster*

CFs, which are typically mirrored for redundancy, provide efficient shared caching and locking for all active nodes within a pureScale cluster. CFs are aware of all pages and locks in use. In the event of a node failure, it is not necessary to freeze the entire cluster. Risks of data loss are lower than for the more rudimentary concurrency mechanisms employed by AlwaysOn.

File and storage management is handled by IBM *General Parallel File System (GPFS),* a distributed file system that is generally recognized as an industry leader in efficiency, scalability and resilience. GPFS has been deployed for more than a decade in high-performance technical as well as commercial applications.

The wide area extension of DB2 pureScale, *Geographically Dispersed pureScale Clusters (GDPC)*, enables active-active clustered failover across multiple sites.

High Availability Disaster Recovery

HADR is a longstanding DB2 feature that may be used to provide HA as well as disaster recovery capabilities. It enables replication and failover to one primary standby and one or two auxiliary standby databases, which may also be employed for read-only data access. Data may be replicated in synchronous, near-synchronous, asynchronous and super-asynchronous modes with varying degrees of potential data loss.

HADR has been widely deployed by DB2 users, and has proved capable of supporting very large databases and transaction volumes. In the event of a system or database failure, standby databases can typically take over in a matter of seconds, although full recovery of data may take longer.

Other HADR features include Delayed Apply, which allows users to delay apply/replay of transaction logs to ensure that errors are not replicated to standby databases; and log spooling, which enables faster recovery by accelerating log replays on standby databases in the event of an outage.

SQL Server AlwaysOn

Overview

Microsoft AlwaysOn is an expanded version of database mirroring in SQL Server 2005 and 2008. Microsoft recommends that organizations *avoid using (database mirroring) in new development work, and plan to modify applications that currently support it*. Users are encouraged to deploy AlwaysOn instead.

AlwaysOn is implemented as an overlay to Windows Server Failover Clustering (WSFC), Microsoft's strategic server-level cluster platform. WSFC is in turn based on the earlier Microsoft Cluster Service (MSCS).

Two types of configuration are supported: Failover Cluster Instance enables single database failover to *cold* standby servers; Availability Groups enable failover of multiple databases to *active* standby servers. This approach is illustrated in figure 7.

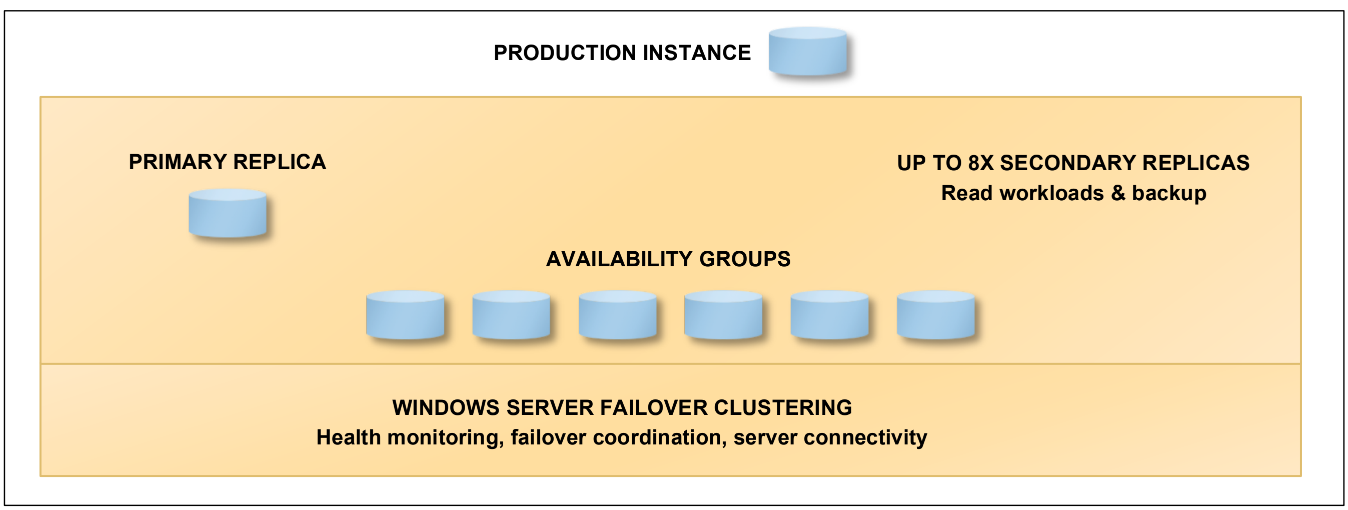

Figure 7: *SQL Server 2014 with AlwaysOn Availability Groups*

Availability Groups combine a production database, a primary replica (which hosts master copies of data and supports read and write operations) and secondary replicas (which may be employed for read-only applications and backup).

Microsoft expanded the maximum number of secondary replicas supported from four in SQL Server 2012 to eight in SQL Server 2014. One or two secondary replicas may employ synchronous replication, or all may operate in asynchronous mode. Although the In Memory feature for SQL Server 2014 is in principle supported by AlwaysOn Availability Groups, In Memory data on secondaries cannot be read.

There are no equivalents to a number of key HADR features, including near-synchronous replication mode, Delayed Apply, and log spooling.

There are also significant differences in how HADR and AlwaysOn handle movement of transaction logs between primary and secondary databases. HADR automatically moves logs to the secondary as soon as transactions are applied. In an AlwaysOn environment, a delay in replaying logs on the secondary may cause Transaction Log Full problems – logs cannot be moved from primary databases until the secondary has caught up.

User Experiences

While DB2 pureScale and HADR typically support business-critical systems, AlwaysOn has more commonly been employed for replication of data from transactional to reporting servers. DB2 database sizes and workloads have been significantly larger.

Early experiences with AlwaysOn also indicate that it is a highly complex solution set, requiring high levels of administrator intervention. A great deal of customization is typically required to bring systems into production. Ongoing software maintenance tasks, and planned downtime for these, also tend to be substantial.

Complexity further increases risks of unplanned outages – there are more potential points of failure. Complex systems may be able to achieve near-100 percent availability in test conditions. However, they rarely do so in practice. This is particularly the case in production environments characterized by mixed, fluctuating workloads.

Switching from primary to standby servers requires more manual intervention than is the case for DB2-based solutions. Even if failover occurs rapidly, more time is required to recover and reinstate data. Moreover, in the event of an unplanned outage, data is more likely to be impacted than if DB2 pureScale or HADR are employed.

These vulnerabilities are compounded by tight integration with WSFC. Failures in the latter may also bring down clustered SQL Server databases. The number of potential points of failure becomes significantly larger.

A number of factors contribute to availability and recovery challenges. These include database and workload characteristics, system complexity, stability of software content and sophistication of operational practices. In all of these areas, AlwaysOn lags DB2 10.5-based solutions by wide margins.

Performance Optimization

DB2 10.5

DB2 has been employed for business-critical transaction processing systems for close to 20 years, and has benefited from performance optimization features in successive versions. Most recently, these have included enhancements in DB2 9.5 (2008), 9.7 (2009) and 10 (2012). The effects have been cumulative.

DB2 10 introduced multi-core parallelism feature enabling server thread to core ratios to be adjusted automatically for optimum performance, and improved algorithms addressing other functions. Transactional enhancements, including – most recently – shadow tables, have continued in DB2 10.5.

IBM also offers a specially packaged appliance, PureData System for Transactions, which combines DB2, DB2 pureScale, Linux on x86 hardware and midrange disk arrays. The system is designed and tuned specifically for high-volume transaction processing applications. HADR is also supported.

OLTP Feature

Design and Delivery

The In-Memory OLTP feature of SQL Server 2014 is based on *Hekaton* technology developed in the Microsoft Research Division. It is implemented as a new database engine that allows administrators to designate specific tables to be stored in main memory (*memory optimized tables*) rather than disk. It employs new (to SQL Server) row-based data structures, and concurrency control and persistence mechanisms.

According to Microsoft, the design focus was on two types of application: (1) high-volume transactional applications with extremely high write rates such as securities trading, travel reservations, order processing and very large websites, and (2) applications with business logic in stored procedures (*we usually look at Web applications using such architecture*).

The In-Memory OLTP feature, which operates alongside the conventional SQL Server engine, was announced by Microsoft and became availability as a Community Technology Preview (CTP) a.k.a. beta test offering in June 2013. A second CTP followed in October 2013 with general availability in April 2014.

Among the SQL Server user community, the In-Memory OLTP feature has – as Microsoft has acknowledged – been the subject of exaggerated expectations. The company has cautioned that users should not anticipate that the gains offered by this feature will compensate for performance shortfalls caused by inadequate user design and implementation of SQL Server-based applications.

User Experiences

Early users of the In-Memory OLTP feature have included e-commerce, online gaming and trading, and cloud service businesses. These had typically reached or were approaching the scalability limits of SQL Server 2012. Others have adopted SQL Server 2014 because of expanded AlwaysOn or Azure support, or as part of regular development and testing programs for new Microsoft software.

Performance experiences have varied widely. Users have reported between seven and 12 times higher transactional performance compared to SQL Server 2012, with larger improvements in batch processing. These experiences were, however, often for specific high-end workload subsets, or were based on proof of concept tests.

Microsoft claims have ranged from *10 times* to *30 times* higher performance than for SQL Server 2012, and the company has also cited *two to five times higher scalability*. Results appear to be highly application- and workload-dependent. A great deal of tuning and testing was also said to be required before systems could be brought into production, along with close monitoring and ongoing intervention by administrators afterward.

Limitations

Microsoft recommends that the In-Memory OLTP feature should be limited to dual-socket servers. Although some early users deployed four-socket machines, performance degradation was typically unacceptable. It is unclear when larger configurations will be supported.

The company also recommends that data in in-memory tables should not exceed 256 gigabytes (GB). Because organizations allow for workload spikes, the practical limit will tend to be 128 GB (a minimum 2:1 ratio of data to RAM is recommended) or less. According to Microsoft, the 256 GB limit will be increased in the future. In the meantime, *continuous monitoring* should be employed to ensure that it is not exceeded.

The In-Memory OLTP feature does not support most types of transaction across multiple databases; data compression; use of large objects (LOBs), triggers, and other common SQL Server functions; data types such as text, images and XML; SQL Server Change Data Capture (CDC) and Transparent Data Encryption (TDE); and numerous T-SQL constructs. Requirements for these will, according to Microsoft, be addressed in future versions.

There are additional implications for availability. Memory utilization by the In-Memory OLTP feature must be closely monitored – if memory becomes full, updates fail – and systems must be taken offline in order to change indexes for in-memory tables.

Microsoft claims that the OLTP Feature is *fully integrated* with other components of SQL Server 2014. This is, however, clearly not the case at present.

Other Capabilities

Data Compression

Overview

The benefits of data compression have been widely documented. In addition to reducing disk space requirements, compression may improve performance by enabling higher processor, main memory and I/O throughput. A wide range of data movement processes – including copying, replication and backup – may also be accelerated.

Higher efficiency typically generates *ripple effects* across entire database infrastructures. For example, cost savings may be generated in disk and tape storage systems, backup media and network bandwidth. Smaller database sizes may also reduce costs for server hardware and systems software, and for storage software tools priced on a per terabyte basis.

DB2 10.5 and SQL Server 2014 both implement columnar compression. Columnar technologies, however, allow systems to process only data in specific columns. In transaction processing environments characterized by more diverse reads and writes, however, it is a great deal less effective.

User Experiences

In DB2 10.5, non-columnar compression is implemented through Adaptive Compression, a new suite of algorithms introduced in DB2 10 that integrates table, page and index compression techniques. The suite is more efficient than comparable algorithms in SQL Server 2014.

Two other factors also come into play:

1. While SQL Server primarily compresses tables and indexes, DB2 Adaptive Compression extends to a broader range of data structures, including temporary tables, log files, large objects (LOBs), values, XML data and others.

2. DB2 space reclamation mechanisms are more granular, and operate automatically. Space reclamation processes are more rapid and effective than is the case for SQL Server.

DB2 10.5 users have routinely experienced overall database compression levels of 80 percent higher (i.e., databases are reduced to 20 percent or less of their previous size). For workloads that are not CPU bound (i.e., where performance was not determined primarily by processor speed), Adaptive Compression also typically delivers 10 to 15 percent higher performance due to lower I/O loading.

In comparison, SQL Server 2014 continues to rely primarily on page-level techniques introduced in SQL Server 2008. In transaction processing applications, high levels of compression were often reported during initial database migrations – this was particularly the case when organizations were moving from poorly optimized legacy databases. Ongoing levels were, however, typically lower.

Users have reported compressions levels of 25 to 90 percent, depending on applications and workloads, with an overall average in the 40 to 60 percent range.

This picture should, however, be qualified. Compression levels cited by SQL Server users were often selective (e.g., they did not include indexes), were for comparatively simple and stable data structures, and/or were for individual tables rather than entire databases. The 80 percent or higher compression levels cited by DB2 users typically refer to overall database sizes.

A further differentiator should be noted. SQL Server 2014 non-columnar compression typically requires a great deal more administrator time and effort than is the case for DB2 10.5. For example, identification of compression opportunities is not automatic – Microsoft recommends that users should regularly search for unused space – and compression routines must be continuously reset as data structures and workloads change.

Workload Management

DB2 10.5

Workload management is a longstanding DB2 strength, which has been further enhanced in DB2 10.5. DB2 capabilities in this area are derived from mainframe architecture, and draw upon mainframe strengths in managing diverse concurrent workloads. Organizations may realize higher levels of capacity utilization over time than with less well-optimized databases.

The DB2 10.5 Workload Manager enables highly granular, automated prioritization, along with resource allocation, queuing and real-time monitoring and management of workloads generated by hundreds or thousands of separate query jobs.

A key benefit is that service level agreement (SLA) targets may be met in a highly cost-effective and reliable manner. Priorities may be set based on user group, query type, time of day and other variables. Up 64 primary classes and 3,904 subclasses of service may be defined.

These strengths provide particular value in environments characterized by diverse transactional and/or query mixes. Such environments include organizational data warehouses that must handle a wide range of query types and sizes with varying degrees of time-sensitivity.

SQL Server 2014

Microsoft's key workload management solution, Resource Governor, was first introduced in SQL Server 2008, and was incrementally enhanced in SQL Server 2012 and 2014. Although it enables administrators to assign workload priorities to pools of processor, I/O and storage resources to reflect service level targets, software mechanisms are more rudimentary and less granular than those of DB2 10.5.

Resource Governor has also been extended by Microsoft to support AlwaysOn Availability Groups, although its cluster management capabilities are a great deal less mature than those of DB2 pureScale and HADR. In standalone as well as clustered environments, the Microsoft approach is commonly characterized as *labor-intensive* in that extensive administrator time and effort is typically required.

Resource Governor also supports the SQL Server 2014 OLTP feature. There appears, however, to have been little real user experience with this capability to date. It is unclear how well it would function in practice.

Automation

Automation capabilities in DB2 have been progressively enhanced for more than a decade. Process structures are more streamlined and integrated than for SQL Server 2014. Fewer steps are required for a wide range of database and storage administration tasks, and automation is more sophisticated and pervasive.

These strengths are reinforced by unique IBM autonomic technologies. Autonomic computing, meaning the application of advanced artificial intelligence technologies to IT administration and optimization tasks, has been a major IBM development focus since the late 1990s. The company is the recognized industry leader in this area.

Autonomic technologies are employed in a variety of features, including those shown in figure 8.

FEATURE	FUNCTION
Automatic storage management	Monitors & automatically creates, extends & adds storage device containers to support database growth across disk & file systems. Redefines storage paths as needed.
Self tuning memory manager	Tunes database memory settings & adjusts these in real time during run time to optimize performance for one or multiple concurrent databases. Increases DBA productivity, improves performance up to 10x & reduces risks of bottlenecks.
Automatic maintenance • Automatic/real-time statistics collection	Determines whether statics need to be updated, & initiates collection for tables where this is the case. Real-time statistics may be generated in under five seconds if required.
Automatic reorganization	Evaluates updated tables or indexes, determines whether reorganization is required, & schedules such operations during predefined periods.
Automatic database backup	Conducts online &/or offline backups, including incremental & snapshot backups, according to predefined schedules & criteria. Backup tuning of memory buffers & threads is performed autonomically.
Advisor Tools	Configuration Advisor automatically generates & tunes database configuration parameters; Design Advisor assists in designing & tuning queries & indexes.
Data Compression	Automates administrative functions for table, index & backup compression. Enables compression dictionary creation during load operations.
Health Monitor	Automates processes involved in health monitoring, alerting & statistics collection & analysis.
Query Optimizer	Enables policy-based determination of optimum query execution patterns to minimize overall resource consumption based on performance, time to deliver results, cost, availability other parameters as appropriate.
Utility Throttling	Regulates operation of maintenance utilities to minimize performance impact during production periods, based on administrator-defined policies.
Silent installation	Allows DB2 installation based on application-specific setup & configuration information; i.e., no user input is required. Enables rapid startup & minimizes installation footprint
Workload Manager	Enables fine-grain resource allocation, monitoring & management of workloads based on service classes, workload characteristics, elapsed time, time of day & other criteria. Integrates with AIX, Linux & other external workload management facilities.

Figure 8: *Major DB2 10.5 Autonomic Features*

The DB2 self-tuning memory manager (STMM), in particular, is one of the industry's most advanced self-tuning technologies.

The most obvious advantage of DB2 10.5 automation strengths is higher DBA productivity. However, there are also significant benefits in performance (system parameters may be adjusted to handle changing workloads more rapidly and efficiently) and availability (risks of performance bottlenecks and human error are reduced).

Although SQL Server 2014 offers a number of functionally similar automation features, these are more limited than DB2 10.5 equivalents and tend to offer productivity gains for comparatively stable applications and workloads. In more dynamic environments, administrative overhead escalates rapidly.

Basis of Calculations

Installations

Cost comparisons presented in this report were based on the installations summarized in figure 9.

FINANCIAL SERVICES COMPANY	MANUFACTURING COMPANY	CLOUD SERVICE PROVIDER
BUSINESS PROFILE		
Diversified retail bank $25+ billion assets 5,000+ employees 4 million customers 2 data centers	Electronics manufacturer $3 billion sales 20 production & distribution centers 7,000 employees 2 data centers	Application service provider 200,000 customers 700 employees 3 data centers
APPLICATIONS		
CRM system	SAP ERP system	CRM, finance & HR, billing & payments, e-commerce, various
DOWNTIME		
IBM DB2 10.5 with DB2 pureScale		
90 minutes per year Three-year costs: $772,371	80 minutes per year Three-year costs: $533,907	105 minutes per year Three-year cost: $472,500
Microsoft SQL Server 2014 with AlwaysOn Availability Groups		
16 hours per year Three-year costs: $8,238,624	14 hours per year Three-year costs: $5,606,164	12 hours per year Three-year costs: $3,240,000
DISASTERS		
DB2 10.5 with DB2 pureScale		
Recovery time: 60 minutes Cost: $584,294	Recovery time: 60 minutes Cost: $383,755	Recovery time: 60 minutes Cost: $190,000
Microsoft SQL Server 2014 with AlwaysOn Availability Groups		
Recovery time: 20 hours Cost: $19,423,847	Recovery time: 24 hours Cost: $11,052,144	Recovery time: 16 hours Cost: $8,022,000

Figure 9: *Installations Summary*

Cost Calculations

Financial Services Company

Calculations were for outages affecting a centralized CRM system handling online as well as call center and branch interactions with customers. Costs of downtime include customer attrition, lost cross-sell and upsell opportunities and lost customer acquisition costs. These were based on industry norms adjusted for the size of the bank and the composition of its customer base.

Severe outage costs include the same variables, plus remedial business costs including customer notifications, additional query handling, reimbursement for customer financial losses, and incentives to retain the loyalty of affected customers.

For the protracted outage caused by AlwaysOn recovery delays, allowance was also made for administrative, marketing, public relations, legal and regulatory costs. Calculations were again based on adjusted industry norms. Costs of downtime as well as severe outage costs assume a customer lifetime value (CLV) of seven years.

Manufacturing Company

Costs were calculated using standard methodologies quantifying the effects of supply chain disruption. Methodologies were adjusted for industry, company size, sales volume and supply chain characteristics. Costs include the following components.

Operational disruption includes costs of idle and underutilized capacity, including personnel costs, handling of delivery delays (including distribution center and transportation costs), and additional inventory carrying costs. Also included are costs of change for ordering, production scheduling and other affected processes.

Customer penalties include late delivery and imperfect order fees, along with buyback costs such as rebates. Costs of potential customer and future sales loss and are not included, because of uncertainties as to the extent to which these would occur.

Financial costs include costs of customer billing and payments processing delays, along with costs of disruption to financial processes. Calculations allow for additional costs of impaired cash flow. Inventory-related costs are included in supply chain disruption totals.

Calculations allow for appropriate cascading effects.

Cloud Service Provider

Costs were calculated based on user-supplied estimates of lost revenues per hour, including fee income, rebates, and customer attrition.

For the protracted outage caused by AlwaysOn recovery delays, allowance was also made for administrative, marketing, public relations, legal and other costs to mitigate damage to customer businesses as well as negative industry perceptions. In practice, it could be expected that brand value and share prices would also be impacted.

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ITG was an early innovator and pioneer in developing total cost of ownership (TCO) and return on investment (ROI) processes and methodologies. In 2004, the firm received a Decade of Education Award from the Information Technology Financial Management Association (ITFMA), the leading professional association dedicated to education and advancement of financial management practices in end-user IT organizations.

Client services are designed to provide factual data and reliable documentation to assist in the decision-making process. Information provided establishes the basis for developing tactical and strategic plans. Important developments are analyzed and practical guidance is offered on the most effective ways to respond to changes that may impact complex IT deployment agendas. A broad range of services is offered, furnishing clients with the information necessary to complement their internal capabilities and resources.

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