AUDIT REPORT
Data Centers
Multi-Agency
January 2019

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AUDITOR’S REPORT

The objective of our audit of data centers operated by the City and County of Denver’s Technology Services agency and by the Denver International Airport’s Business Technologies Division was to evaluate the four data centers against applicable standards to ensure the security and availability of technology assets and to provide information technology services. I am pleased to present the results of this audit.

The audit revealed that Technology Services and Business Technologies need to address several issues and improve their data center operations. The City’s General Services Department also needs to implement new controls over the management of critical data center facilities overseen by Technology Services.

By addressing data center locations and weak environmental controls, by improving ongoing software application reviews, and by implementing cost accounting practices, Technology Services and Business Technologies can improve their data center operations. In addition, through the adoption of a data center control framework and through better collaboration between Technology Services and Business Technologies, the agencies will be able to ensure a more secure and resilient technology environment. Developing and implementing policies and procedures for technology infrastructure will help General Services and Technology Services prevent system failures that could cause a loss of data. Our report lists several related recommendations to address these concerns. In addition, we identified security-related findings, which have been communicated separately to management of Technology Services and Business Technologies for their remediation.

This performance audit is authorized pursuant to the City and County of Denver Charter, Article V, Part 2, Section 1, “General Powers and Duties of Auditor,” and was conducted in accordance with generally accepted government auditing standards. Those standards require we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

We extend our appreciation to the Technology Services, General Services, and Business Technologies personnel who assisted and cooperated with us during the audit. For any questions, please feel free to contact me at 720-913-5000.

Denver Auditor’s Office

[Signature]

Timothy M. O’Brien, CPA
Auditor
Objective
This audit evaluated the two data centers operated by the City and County of Denver’s Technology Services agency and the two data centers serving Denver International Airport. The data centers were assessed for efficiency and effectiveness of operations against applicable standards to ensure the security and the operability of technology assets, such as equipment, facilities, and infrastructure.

Background
Data centers house critical information technology (IT) assets, including servers, routers, and other devices. Technology Services and the airport are each responsible for a primary and a secondary data center. These four data centers use a mix of cloud-based and in-house technology solutions.

Technology Services provides all IT-related infrastructure and services to the City, including support for the data centers audited in this report. The General Services Department provides facility support, including maintenance and operation of City facilities that support Technology Services’ data centers. Denver International Airport’s Business Technologies Division is responsible for the IT infrastructure and services used by the airport, including the data centers audited.

REPORT HIGHLIGHTS

Highlights
Data Center Infrastructure Cannot Easily Adapt to Changes in Operations

- Environmental controls at one City data center do not provide consistent temperature and humidity for the data center to function at optimal performance.
- The existing data centers do not provide sufficient geographic diversity.
- Technology Services cannot provide a complete and accurate inventory of data center hardware, applications, databases, and other equipment.

Data Center Operations Lack Application Reviews, Cost Data, and Collaboration between Technology Services and Business Technologies

- No process is in place to review and approve the continuing use of software applications running in the data centers to ensure they still provide appropriate value.
- The Technology Services agency and the Business Technologies Division do not track the costs of application services, making it impossible to truly determine the cost of providing or changing these services.
- The Technology Services agency and the Business Technologies Division do not share their data center management tools and knowledge, so they miss out on opportunities for cost-savings and efficiency.

Technology Services and the Airport Should Employ Consistent Operational Standards at All Data Center Locations

- Technology Services has not adopted comprehensive data center operations and control frameworks to ensure consistent operations.
- The City’s General Services Department operates without complete policies and procedures to provide facility services at Technology Services’ data centers.
- Employees sometimes make unauthorized changes in Technology Services’ data centers.
- The continuity of operations plan for the airport data centers is outdated.

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BACKGROUND

Technology is critical in operating any modern-day organization, whether it is a private business or a government entity. For large organizations like the City and County of Denver, information technology (IT) equipment, hardware, and facilities are typically centralized in locations called “data centers.”

Due to the magnitude of the City’s operations and its IT needs, the City’s Technology Services agency and the Denver International Airport each operate two data centers—one primary and one secondary. These facilities support the technology used by City agencies and thousands of City employees, which, in turn, helps the City provide critical services to its residents.

The Basics of Data Centers

A data center is a secure facility used to provide the best operating environment for critical technology devices, including servers, routers, switches, and firewalls. Devices kept in data centers fall into two broad categories: computing devices and the network devices that control computer system activity.

Servers—computing devices that provide data to other computers—are generally housed in data centers. Many types of servers exist, including web servers, software application servers, database servers, mail servers, and file servers. Each type runs software specific to the purpose of the server, and each is designed to provide data back to users’ devices.

Data centers have evolved greatly from the first general-purpose electronic computer in 1946—which was so large it needed its own room—to today’s “blade servers,” which allow the storage of eight servers in a space equal to the size of a household microwave. As a result, a single data center can now accommodate all the devices, equipment, and connections needed to act as a central nexus for an organization’s entire IT framework.
Several Alternatives Exist to Provide Data Center Services

Data center services can be delivered using one or a combination of the following methods, as is also illustrated in Figure 1 on page 3:

- **An on-premise facility** – where an entity owns and manages its data center with its own resources.
- **A co-location facility** – where an entity rents space for servers and other computing hardware. This option typically provides the building, cooling, power, bandwidth, and physical security; the customer provides servers and storage.
- **Managed hosting** – where a service provider leases dedicated servers and associated hardware to a single customer and manages those systems on the customer’s behalf in the service provider’s data center.
- **Cloud services** – where an entity purchases software and data center services that are provided by a third-party company. The third party stores, manages, and processes data for the customer.

Technology Services’ and the airport’s data centers employ a hybrid of these options using both on-premise and cloud-based services.

As an example, Technology Services uses Microsoft’s Office 365 to provide email and personal file storage to City employees. Office 365 runs in Microsoft’s global data centers, which City employees remotely access.
access at work, at home, or elsewhere. By using Office 365, Technology Services does not have to purchase and manage the software or hardware needed to provide email and file storage.

Critical Environmental Controls for Data Center Design

Temperature, Humidity and Water Detection – Data centers need to have proper controls to prevent and detect both water leaks and unacceptable changes in temperature or humidity. Computing devices, from routers to servers, are all designed to work best at specific temperature and humidity levels. The ability to monitor and adjust for these levels is critical in data center design, so that physical hardware is not damaged.

All computing devices create heat while operating. Therefore, thousands of computing devices in a single data center—such as in those operated by Technology Services and Denver International Airport—can generate large amounts of heat that then require compensating cooling measures. In extreme examples, some of the world’s largest tech companies are exploring innovative locations for their data centers in order to combat high cooling costs. Microsoft is exploring the possibility of underwater data centers, and Facebook established a data center in northern Sweden, just 70 miles south
Because of the significant heat generated in data centers, dedicated air conditioning or other cooling systems are necessary; these air conditioning systems can also be used to adjust humidity levels.

It is also important to be able to detect if water is present in a data center, such as flooding caused by a broken pipe. Computing devices and network devices will fail and often suffer complete destruction when immersed in water. Prompt reactions to control water flow can prevent potential damage.

### Power Supply and Equipment Failure

Because computing devices require constant power to operate, a sufficient, redundant power supply is needed to prevent data center equipment from being shut off. A temporary loss of power can be costly for the City and can halt services. A 2016 study sponsored by Vertiv and independently conducted by the Ponemon Institute sampled 63 data centers from across various industries and found that the average cost of a data center outage was about $9,000 per minute and that the average power outage lasted 95 minutes for an average cost of about $855,000 per outage—including the cost for replacement equipment and lost productivity.

When computing devices abruptly lose power, it causes a hard shutdown. Because the hardware does not turn off as it is designed, hard shutdowns can cause significant wear and tear to electronic components, eventually resulting in a loss of data and even physical destruction of the hardware. As an example, a hard drive has a small, circular, magnetic platter that spins at over 10,000 revolutions per minute; if power is abruptly cut off, it is possible the hard drive head could touch the platter, destroying the hard drive.

Standards from the Uptime Institute state that, because of these risks, the best data centers are designed to minimize power outages and are located so that they can connect to two separate main power grids from a local utility company. In such data centers, there would

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3. The Ponemon Institute is a research center focused on promoting privacy, data protection, and information security practices. It conducts independent research with the goal of providing a better understanding of security trends and potential threats.
5. The Uptime Institute is an American advisory organization that developed and administered tier standards and certifications for data centers.
be multiple uninterruptable power supplies—basically large batteries that will start supplying power if the main power grids stop working. The uninterruptable power supplies would be designed to function until separate, on-site backup generators can be started. The institute’s standards also indicate the best data centers would have multiple backup generators, each capable of supplying all the power needed so the loss of one generator would not shut down the entire data center.

**Physical Security** – If someone can physically gain access to computer hardware, they are then able to control that hardware. Therefore, the need to keep physical computer hardware under lock and key is critical for cybersecurity, and the physical location of a data center is also a closely guarded secret to prevent unauthorized access.

The best data centers treat access the way a bank treats access to its vault: Only authorized people with a need to be physically present to work in the area should have access. The standards set by the National Institute of Standards and Technology define these security arrangements. The principle of “least privilege” limits access to only those performing specific job-related duties. Physical access to data centers is typically controlled using features such as key cards, biometric locks, and mantraps.

Data Centers for Technology Services and the Airport

Technology Services and Denver International Airport each own and operate two data centers—one primary and one secondary.

Technology Services’ two data centers support over 400 software applications using a mix of over 1,500 devices, including mainframes, stand-alone servers and virtual servers. Technology Services plans to replace its on-premise secondary data center. The agency also uses cloud-based services for some of its operations, such as Office 365 (for email and file storage) and Workday (for accounting and human resources). Meanwhile, the airport’s two data centers support over 150 software applications. The airport requires its own data centers because it is a standalone entity within the City that needs to provide real-time support for its critical operations.

The Uptime Institute created its standard Tier Classification System to effectively evaluate data center infrastructure in terms of the

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7 The National Institute of Standards and Technology is a laboratory and non-regulatory federal agency within the U.S. Department of Commerce. The institute’s Special Publication 800-53 details security controls and assessment procedures for data centers.

8 For definitions of these and other key terms, reference “Appendix A – Glossary” on page 46.
infrastructure’s ability to provide critical services. The Tier Classification System provides a consistent method to compare what are typically unique, customized facilities based on expected performance. Possible scores range from 1 at the lowest to 4 at the highest.

A data center cannot receive a rating lower than 1; therefore, a data center with minimal or no controls would still be rated a level 1. A level 4 data center would provide sufficient redundancy in all attributes to minimize any possible downtime no matter the circumstance, including major disasters.

As shown in Table 1, each of Technology Services’ and the airport’s data centers might be rated as levels 1 to 3 based on the audit team’s assessment of Uptime Institute standards.

### Table 1. Classifications for Technology Services’ and Airport Data Centers

<table>
<thead>
<tr>
<th>Technology Services</th>
<th>Tier Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Data Center</td>
<td>2</td>
</tr>
<tr>
<td>Secondary Data Center</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Denver International Airport</th>
<th>Tier Classification</th>
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<tbody>
<tr>
<td>Primary Data Center</td>
<td>3</td>
</tr>
<tr>
<td>Secondary Data Center</td>
<td>2</td>
</tr>
</tbody>
</table>

Source: Auditors’ assessment based on the Uptime Institute’s Tier Classification System.

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10 A Tier I data center would provide basic capacity with an uninterruptible power supply and generator. A Tier II facility would include redundant power and cooling, while a Tier III facility would require no shutdowns to perform equipment replacement or maintenance.
FINDING 1

Data Center Infrastructure Cannot Easily Adapt to Changes in Operations

In assessing the infrastructure for Technology Services’ and the airport’s data centers, auditors identified several areas of concern, including that Technology Services’ secondary data center lacks sufficient protection from environmental risks, and the agency does not have a complete and accurate inventory of its equipment and hardware. By implementing the resulting recommendations, the data centers audited will operate more efficiently and effectively.

Environmental controls are essential to data center operations because of the sensitivity and high cost of critical IT infrastructure.

Auditors assessed the environmental controls at Technology Services’ and the airport’s data centers, and we determined Technology Services’ primary data center has good environmental controls in place. However, in assessing the agency’s secondary data center, we identified several risks that do not offer sufficient protection to data and the underlying equipment.

Specifically, at Technology Services’ secondary data center, we observed:

- Evidence of water stains within ceiling tiles, as seen on page 8;
- Plywood comprising parts of the building walls, which underlies inherent structural issues; and
- Vegetation engulfing outside electrical and data lines.

These issues arose because the facility that houses Technology Services’ secondary data center was initially designed for another purpose and was not appropriately renovated to house a data center. The renovations were not done because of the high cost needed to create and maintain a data center facility and because of a lack of City funding at the time the data center was placed in the existing building. Technology Services is aware of these issues and monitors the facility closely; however, this does not negate the potential for damage to sensitive data and equipment within the data center that exists because of these environmental risk factors.

The standard for data center environmental controls from the National Institute of Standards and Technology offers extensive guidance on
the steps necessary to ensure environmental protection of sensitive IT equipment. The institute specifies that data should be protected against excessive heat, water damage, and fire hazards. It also advises that data centers’ locations be separated in such a manner that a disruption to one data center location will not disrupt other data centers.

When assessing the location of Technology Services’ and the airport’s data centers, we determined there is not enough geographic diversity between primary and secondary sites. The primary data centers are less than 2.5 miles from their corresponding secondary data centers—placing them at the same risk of being affected by environmental factors such as snowstorms, which occur frequently in Colorado. Severe snowstorms can cause traffic delays, affect roads, restrict access to buildings, and cause power outages. (The 30-year average seasonal snowfall for Denver is 55.3 inches as recorded by the U.S. National Weather Service.)

Technology Services had identified the need to address environmental and geographic location issues in its two data centers and, during

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the audit, had an active project in place to identify suitable ways to address these risks. Given the large costs needed to bring the current secondary data center location into compliance with the National Institute of Standards and Technology’s environmental control guidelines, City officials determined that the most cost-effective option was to contract with a suitable third-party co-location provider.

**Airport Internet Service** – In assessing the airport’s environmental controls, we noted that both airport data centers rely on a single internet service provider, which does not offer provider diversity should the provider service be disrupted. Because these facilities are limited by the existing internet service, it has restricted the airport from creating greater geographic diversity between data centers.

A security control standard from the National Institute of Standards and Technology security recommends that the location between primary and secondary sites should be geographically separate, such that they are not subject to the same environmental impacts as each other.\(^\text{13}\) Therefore, due to the proximity of the primary and secondary data centers, the airport should also evaluate whether the secondary facility ought to be relocated once diverse internet connections are in place.

Business Technologies is aware of the risk related to internet service and has begun obtaining an additional internet service provider, in addition to the current provider.

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**RECOMMENDATION 1.1**

**Relocate Data Center (Technology Services)** – The Technology Services agency should complete the replacement of its secondary data center with a suitable location.

*Agency Response: Agree, Implementation Date – December 2019*

**RECOMMENDATION 1.2**

**Address Internet Service Solution (Business Technologies)** – Denver International Airport should continue implementing a more robust internet service solution as soon as possible.

*Agency Response: Agree, Implementation Date – December 31, 2020*

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RECOMMENDATION 1.3

Assess Secondary Airport Data Center (Business Technologies) – After implementing Recommendation 1.2, Denver International Airport should perform an evaluation to determine if its secondary data center should be relocated or augmented.

Agency Response: Agree, Implementation Date – April 1, 2021

Technology Services’ Inventory of Technology Assets Is Incomplete

Creating and maintaining an accurate inventory of all systems and equipment within a data center is a critical operational need. Without a complete and up-to-date inventory, the process of maintaining and operating a data center is much more difficult.

ServiceNow is the tool Technology Services uses to track all technology equipment, including devices in its data centers. For this audit, Technology Services generated an inventory report from ServiceNow so that auditors could match the equipment physically present in the data centers with those listed in the report. However, upon inspection, auditors quickly discerned the report was incomplete. In an attempt to provide an accurate inventory report, Technology Services generated another report, only for auditors to find that this report, too, was incomplete. As auditors performed testing to determine if an accurate inventory was being maintained, we identified four critical devices, including mainframes, that were missing from the inventory report of Technology Services’ data centers. It was only after several months that Technology Services was able to generate an inventory report that auditors could use for consideration; however, that inventory report still did not accurately reflect the entirety of the data center environment.

Maintaining a complete and accurate inventory is a vital principal, as defined by a security control standard from the National Institute of Standards and Technology. The standard articulates that inventories should accurately reflect the current environment and be updated when there are changes. A change might be something as simple as moving a network device to something major, such as installing or decommissioning a server.

Technology Services has made progress over the past several years to update its inventory; however, without a complete and accurate

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inventory, Technology Services is unable to fully manage its data center operations. If Technology Services does not know what devices are on its network, there is a risk the devices might not be updated, leaving the network vulnerable.

RECOMMENDATION 1.4

**Develop Data Center Inventory Report (Technology Services)** – The Technology Services agency should develop, as soon as possible, a readily available, easy-to-run report that provides a complete and accurate inventory of all data center hardware, software applications, databases, and underlying equipment.

*Agency Response: Agree, Implementation Date – June 2019*

RECOMMENDATION 1.5

**Perform Periodic Review of Inventory (Technology Services)** – The Technology Services agency should develop as soon as possible a process to periodically assess the completeness and accuracy of data center inventory.

*Agency Response: Agree, Implementation Date – June 2019*
FINDING 2

Data Center Operations Lack Application Reviews, Cost Data, and Collaboration between Technology Services and Business Technologies

Auditors reviewed the operational processes used in all four data centers audited and identified the following three areas of concern:

- Software applications running in the data centers are not reviewed for continued need, cost-efficiency, and compatibility with current infrastructure;
- Operational costs for data center software applications are not tracked; and
- The City’s Technology Services agency and the airport’s Business Technologies Division do not share their knowledge and expertise in data center operations.

To address these concerns, we developed recommendations that, if fully implemented, will provide a better data center operational environment and allow the City to be more efficient, identify wasteful or unnecessary applications still in use, and understand the true cost of applications it continues to support.

Neither Technology Services nor Business Technologies Conducts Ongoing Reviews of Software Applications

The City’s Technology Services agency and the airport’s Business Technologies Division each support hundreds of software applications, which enable the City and the Denver International Airport to meet regulatory requirements and provide services to employees and the public. However, auditors found that neither Technology Services nor Business Technologies has implemented a process to evaluate existing applications and software.

The software application life cycle is an integral part of data center operations. The process for choosing, implementing, using, and replacing software is depicted in Figure 2 on page 13. When City agencies and airport divisions initially select a software application that meets their mission and business needs, they collaborate with their respective technology departments to ensure the application is compatible with the current technology infrastructure. However, we found there is no established process to evaluate, on a periodic basis, software applications already in place to ensure they still meet an agency’s business needs, are cost-efficient, and are compatible with current infrastructure.

Without this process, Technology Services and Business Technologies
support diverse software applications that may no longer provide the best fit and may no longer be supported by software vendors. By using unsupported software that has reached the end of its life, organizations can no longer rely on the vendor to support the software and provide updates.

As an example of this risk, using outdated software caused dozens of IRS tax processing systems—including e-file—to be unavailable for 11 hours on Tax Day 2018. Because this outage interfered with millions of Americans’ ability to file their federal income tax returns on time, the IRS extended the filing deadline by one day. In this instance, the IRS was able to resolve the issue by deploying an update to its mainframe.

According to the U.S. General Services Administration, it is best practice for organizations to review projects and systems periodically. Some of the key considerations during a review include:

- Evaluating cost, including ongoing operations and maintenance;
- Reviewing requirements to determine if they have changed since the solution was initially selected;


• Evaluating processes or regulatory requirements to determine if they require modifications;
• Assessing if the existing solution still meets the organization’s needs and functionality; and
• Reviewing the existing solution’s fit with technology infrastructure.

Additionally, the National Institute of Standards and Technology recommends a periodic assessment of software applications to determine if they are performing in accordance with organizational needs and system security requirements.\(^\text{17}\) Software applications should be assessed to determine if they are still effective, secure, and efficient. The federal government noted under the Clinton White House that “senior program managers in federal agencies often pay most of their attention to new projects and carry ongoing projects as necessary budget items. In best practice organizations, however, ongoing projects are reviewed continually along with new projects and go/no-go decisions are made. No project should be allowed to continue indefinitely through failure. Project continuance should be periodically challenged.”\(^\text{18}\)

The cost of continuing to provide service is also a consideration in reviewing software applications. Technology Services and Business Technologies should decide, in coordination with application owners, whether a software application should be supported as is, modified, upgraded, replaced with another product or enterprise application, or be canceled. The effect of not performing recurring assessments results in Technology Services and Business Technologies continuing to support software applications that are costly to maintain and potentially inefficient. This creates a waste of resources, and the application owner may spend extra time using a software application that no longer meets their current needs.

By performing these assessments on a periodic basis, management can better identify software applications and systems that are nearing end-of-life.


RECOMMENDATION 2.1
Perform Periodic Application Review (Technology Services) – Working with the Mayor’s Office, the Technology Services agency should enhance their existing process, as soon as possible, for reviewing the business justification and appropriateness of software applications. This review process should occur at least every three to five years, include all applications, and be done in consultation with application owners.
Agency Response: Agree, Implementation Date – December 2019

RECOMMENDATION 2.2
Perform Periodic Application Review (Business Technologies) – The Denver International Airport’s Business Technologies Division should enhance their existing process, as soon as possible, for reviewing the business justification and appropriateness of software applications. This review process should occur at least every three to five years, include all applications, and be done in consultation with application owners.
Agency Response: Agree, Implementation Date – September 1, 2019

Neither Technology Services nor Business Technologies Knows the Full Cost of Operating Their Data Centers
As both Technology Services and Business Technologies continue to evolve in how they provide data center services—and specifically, software application support—it is critical for officials to understand the cost of providing these services. However, neither Technology Services nor Business Technologies can provide the true cost of supporting and maintaining any of their applications running in the data centers.

While the cost to purchase and implement new software applications is carefully considered, ongoing support costs—including IT personnel, utilities, and infrastructure—are not fully considered or tracked. Once a new software application is put into service, the cost to maintain licenses and the new software vendor support costs are added to Technology Services’ and Business Technologies’ budgets, but no other ongoing support costs are added or identified.

Both the Technology Services agency and the Business Technologies Division have operated as a support service for other City and airport groups and have not broken out the specific costs to support individual software applications. When additional resources—such as more storage or server capacity—are needed because of an existing
software application’s growing needs, Technology Services and Business Technologies acquire and implement these additional resources without cost to the agency that uses the software application. Without the ability to understand and quantify the cost of providing application support, it is impossible for the City and the airport to make good management decisions about these software applications. Lacking cost data prevents even a basic cost-benefit review of any of the over 400 software applications supported by Technology Services or the over 150 software applications supported by Business Technologies.

The Institute for Public Procurement has identified best practices related to government procurement processes. An important part of those processes is to make sure that prices account for all the needs in a procurement request.

With the rise of cloud-based technology and other methods of hosting applications, Technology Services and Business Technologies have alternatives that did not exist before for providing application support services, such as cloud-based services. Therefore, when Technology Services or Business Technologies considers the most cost-effective method to support a software application, agency officials need to know what it will cost to support the application in a Technology Services- or airport-owned data center, compared to what it will cost having it supported in some other capacity.

According to the U.S. General Services Administration, each project and system should be reviewed to determine how current costs compare against projected costs. As both Technology Services and Business Technologies begin to perform reviews of software applications, as described in Recommendation 2.1 and 2.2 above, being able to identify the full cost of a software application will be an integral part of these reviews.

Because individual agencies or departments do not see the cost increase in supporting the existing applications, they do not see any need to review the cost-benefits of the existing applications. Unless agencies can be provided cost data as part of an overall application review process, it will not be possible for agencies to determine the cost-benefit for their software applications and, thus, the agencies cannot determine if an application is cost-effective for the City.

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19 The Institute for Public Procurement was established in 1944 as a not-for-profit educational association. It creates best practices and training related to governmental procurement processes and practices.


One option Technology Services and Business Technologies should consider for tracking these costs is using the City’s accounting system, Workday, and a specific work tag for data center costs, beginning with the 2019 budget.

RECOMMENDATION 2.3

Track Data Center Costs (Technology Services) – The Technology Services agency should track costs associated with providing data center support. These tracked costs should include:

- Personnel costs – including salaries and benefits;
- Building costs – including utilities, insurance and other direct facility costs;
- IT infrastructure costs – including hardware and supporting software, such as operating systems costs; and
- Application-specific costs – including licensing, specific hardware needs, and maintenance costs.

Agency Response: Agree, Implementation Date – December 2019

RECOMMENDATION 2.4

Track Data Center Costs (Business Technologies) – The Denver International Airport’s Business Technologies Division should track costs associated with providing data center support. These tracked costs should include:

- Personnel costs – including salaries and benefits;
- Building costs – including utilities, insurance and other direct facility costs;
- IT infrastructure costs – including hardware and supporting software, such as operating systems costs; and
- Application-specific costs – including licensing, specific hardware needs, and maintenance costs.

Agency Response: Agree, Implementation Date – May 1, 2019
Technology Services and Business Technologies Do Not Share Their Data Center Management Tools

The City’s Technology Services agency and the airport’s Business Technologies Division have each developed their own methods to keep their data centers running efficiently and each uses a variety of tools and techniques toward that end. However, when auditors inquired to Technology Services and Business Technologies regarding the extent to which they collaborate with each other to share knowledge and experience, we determined each agency works independently and rarely shares knowledge of their various tools and techniques. Although the data centers still function under this approach, the lack of collaboration could mean missed opportunities for cost-savings and efficiency.

The Federal Data Center Optimization Initiative was established by the U.S. Office of Management and Budget to improve the efficiency of technology within federal data centers. It includes guidance on cost-savings and the consolidation and closure of existing facilities, as well as improvements in optimization metrics. This guidance recommends the use of a shared-service model to achieve efficiency through collaboration and cost-savings.

The U.S. General Services Administration published its own data center best practices guidance in support of the Federal Data Center Optimization Initiative, stating that best practice is to use a data center infrastructure management tool. This tool brings together previously isolated IT and building facility functions within an organization. The goal is to provide management with a holistic view of a data center’s performance, so they can make fully informed decisions—and monitor their impacts—to ensure energy, equipment, and space are used as efficiently as possible.

Technology Services and Business Technologies each have different sets of data center monitoring tools, which they do not share. Business Technologies uses a data center infrastructure management tool; however, the tool is not being used to its full extent because it does not have all the sensors required to provide reports on energy use for each device, nor does it track total power use in the data centers. Technology Services uses different monitoring tools to provide some of the functionality of a full infrastructure management tool; however, it also does not track power use.

Data center monitoring tools have rapidly evolved with changing technology and with the different methods of providing services. As

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a result, both Technology Services and Business Technologies employ tools that can be more fully utilized to provide critical data on the overall operation, efficiency, and effectiveness of their respective data centers. A standard software package for data center infrastructure management would collect and aggregate data reported by energy meters, sensors, and IT equipment in a facility, and then generate easy-to-interpret visualizations and detailed reports. This offers the capability to improve and analyze performance and makes benchmarking easier. These outputs also are useful for monitoring current conditions, becoming aware of and diagnosing problems and inefficiency, and tracking trends over time.

A typical data center infrastructure management tool would include inventory capabilities, too, which are useful for prioritizing equipment refreshes and drawing conclusions about the ability to expand or contract the overall computing environment. The tool would also track and highlight stranded infrastructure, underutilized floor space, and over- or under-provisioned servers. Figure 3 illustrates some of the primary capabilities of a data center infrastructure management tool.
Data on energy use is meaningful to track long-term trends, benchmark progress and performance, perform diagnostics, and alert data center operators to impending or ongoing system failures. Tracking such data is so important that a federal executive order required federal data centers to have advanced energy-metering equipment in place capable of tracking power usage effectiveness by the end of fiscal year 2018, which ended September 30.24

The Green Grid, which developed the metric for “power usage effectiveness,” defines three levels of metering—with each successive level calling for increased monitoring and automation.25 “Intermediate metering” meets the federal minimum requirement for tracking power use by requiring daily, automated data collection at the building level and in some systems.

The best practice among high-performing data centers, however, is to measure energy use more frequently and at a deeper level. The more detailed and frequently obtained the data, the better insight can be gleaned from a data center. “Advanced metering” encourages automated monitoring of power use at a device level: Electricity is tracked from its entry into the facility down to individual components of a data center—power distribution units, heating and cooling equipment, IT equipment, etc. Such detailed metering enables data center operators to pinpoint trouble spots and find excess capacity, which maximizes the possibilities for energy- and cost-savings especially when combined with an infrastructure management tool. By not fully utilizing these tools, Technology Services and Business Technologies are missing opportunities to improve the City’s overall energy sustainability and efficiency.

Advanced metering requires the largest upfront capital cost. If deploying an advanced network of meters at once is prohibitively expensive, Technology Services and Business Technologies can each still make gradual advances toward this best practice by using opportunities to refresh equipment to replace outdated equipment with technology that has built-in metering. In the interim, Technology Services and Business Technologies should each follow intermediate metering practices.


RECOMMENDATION 2.5

Collaborate to Share Tools and Knowledge – The City’s Technology Services agency and the airport’s Business Technologies Division should share knowledge, tools, and the technology they use to manage their data centers. These combined tools should provide the equivalent of a data center infrastructure management tool set.

Agency Response: Agree, Implementation Date – May 1, 2019 (Business Technologies); June 1, 2019 (Technology Services)

RECOMMENDATION 2.6

Track Energy Use (Technology Services) – The City’s Technology Services agency should set up a process as soon as possible to track, at a minimum, total energy costs for each data center. In the long term, the agency should perform an analysis of energy costs down to the device-level starting in 2020.

Agency Response: Agree, Implementation Date – December 2019

RECOMMENDATION 2.7

Track Energy Use (Business Technologies) – The Denver International Airport’s Business Technologies Division should set up a process as soon as possible to track, at a minimum, total energy costs for each data center. In the long term, the division should perform an analysis of energy costs down to the device-level for each data center starting in 2020.

Agency Response: Agree, Implementation Date – May 1, 2019
FINDING 3
Technology Services and the Airport Should Employ Consistent Operational Standards at All Data Center Locations

Auditors found several areas where Technology Services and the airport should improve their overall data center operations. Among the concerns auditors identified:

- Technology Services does not have a comprehensive data center control framework;
- Policies and procedures for data center facilities are insufficient;
- Procedures for software and hardware changes are not consistently followed; and
- The airport’s continuity of operations plan is outdated.

Addressing these items will enhance the efficiency of the data centers’ operations and improve their internal controls.

A good starting point for any effective data center operation is to adopt a control framework, which provides the guidelines and requirements for the design and installation of the facility. The Telecommunications Industry Association’s standard for data center quality provides a comprehensive structure for data center design, facility planning, and cabling.\(^{26}\) In addition, the National Institute of Standards and Technology’s security controls standard for data centers provides guidance on policies and procedures, on maintaining a complete and accurate inventory, and on implementing changes to a data center.\(^{27}\)

Auditors sought to determine what data center control framework Technology Services and Business Technologies have each used in their designs. In doing so, we determined Business Technologies has adopted the Telecommunications Industry Association’s standard and has operated under this framework for several years.

Alternatively, Technology Services’ data centers are based off components of various frameworks; however, those facilities have yet to fully adopt a single framework, such as the Telecommunications Infrastructure Standard for Data Centers, TIA-942-B (Revision of TIA-942-A),” Telecommunications Industry Association (July 2017), p. 28-33. Provided by the City and County of Denver’s Technology Services agency.

Industry Association’s. Because of this, there are several areas where Technology Services’ data centers exhibit weak operations and inconsistencies in internal procedures.

RECOMMENDATION 3.1

**Adopt Data Center Standards (Technology Services)** – The Technology Services agency should adopt, as soon as possible, a set of comprehensive data center operating standards, such as the Telecommunications Industry Association’s standard for data center quality, called “TIA 942.”

**Agency Response:** Agree, Implementation Date – December 2019

Policies and Procedures for Data Center Maintenance and Problem Management Are Insufficient

Technology Services has insufficient policies and procedures for when periodic maintenance of equipment should be performed and how facility problems are handled. Although Technology Services does have a maintenance and problem management policy, its policy lacks several considerations for controls related to security, environmental factors, periodic maintenance, and testing of equipment in the data centers.

These limited policies and procedures are used by the General Services Department’s facilities division, which is responsible for periodic maintenance of City equipment—including the uninterruptable power supplies and the backup generators used by Technology Services’ data centers.

Without a robust policy governing maintenance and problem management, General Services personnel will be unaware of their responsibilities to maintain equipment, which could lead to outages and loss of data.

The National Institute of Standards and Technology’s standard specifies that policies and procedures should be established in the areas of maintenance and problem management and that those policies and procedures should be disseminated to employees.28

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RECOMMENDATION 3.2

Update Existing Policies – The Technology Services agency should work with the General Services Department to update, as soon as possible, the existing IT asset management policy related to problem management and maintenance. This updated policy should be based on the National Institute of Standards and Technology’s standard 800-53 and should address environmental and security control considerations, periodic testing, and problem resolution.

Agency Response: Agree, Implementation Date – December 2019

RECOMMENDATION 3.3

Create Procedures – After implementing Recommendation 3.2, the Technology Services agency should work with the General Services Department to create procedures related to data center maintenance and problem management.

Agency Response: Agree, Implementation Date – December 2019

When auditors reviewed the process for implementing changes to Technology Services’ and Business Technologies’ data centers, we determined that a documented process had been developed in compliance with the National Institute of Standards control framework. However, at the Technology Services data centers, auditors identified a few instances when employees chose to bypass this required process. As a result, the Technology Services data centers experienced situations when changes were made that affected other systems, potentially rendering them unavailable.

RECOMMENDATION 3.4

Prevent and Detect Unauthorized Changes to Systems (Technology Services) – As soon as possible, leadership of the Technology Services agency should issue a firm directive to agency personnel that no unauthorized changes to systems occur.

Agency Response: Agree, Implementation Date – June 2019
Auditors also sought to determine the preparedness for continuing operations at Technology Services’ and the airport’s data centers in the event of a disaster. When inspecting emergency plans, we determined Technology Services has developed a comprehensive set of plans that includes the restoration of operations in the event of a disaster. However, the airport’s continuity of operations plan for restoring data center operations was outdated, in that it lacked any reference to the secondary data center, because the plan predated the existence of that data center. Not including the secondary data center in the continuity of operations plan puts the airport at risk of not being able to resume data center operations in the event of an emergency or disaster.

The Federal Emergency Management Agency provides relevant guidance for non-federal governments by recommending an annual review of continuity of operations plans and an update to those plans when organizational changes occur.29 Best practices for data centers also note the importance of keeping continuity of operations plans up to date and of practicing these plans frequently to develop operational resiliencies.

As an example for how consequential such plans are for data centers: In the aftermath of Hurricane Katrina in 2005, the National Finance Center succeeded in never missing payroll for over 500,000 federal employees—despite the center’s data center being located in New Orleans, near where Katrina caused the most damage.30 This was because the finance center—a shared service provider under the U.S. Department of Agriculture—had detailed disaster recovery and business continuity plans in place for its data center, which were deployed before the hurricane struck Louisiana.

By updating its continuity of operations plan, the airport’s data centers will be better prepared and better able to respond accordingly in the event of an emergency or disaster.

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RECOMMENDATION 3.5

Update Continuity of Operations Plans (Business Technologies) – The Denver International Airport’s Business Technologies Division should work with Denver International Airport’s COOP (continuity of operations planning) administrator to create an annual process to review and approve continuity of operations plans for its data centers.

Agency Response: Agree, Implementation Date – May 1, 2019
RECOMMENDATIONS

1.1 **Relocate Data Center (Technology Services)** – The Technology Services agency should complete the replacement of its secondary data center with a suitable location.

   **Agency Response:** Agree, Implementation Date – December 2019

   **Agency Narrative:** Technology Services agrees with the finding. We will continue replacing the secondary data center.

1.2 **Address Internet Service Solution (Business Technologies)** – Denver International Airport should continue implementing a more robust internet service solution as soon as possible.

   **Agency Response:** Agree, Implementation Date – December 31, 2020

   **Agency Narrative:** We agree with this recommendation. DEN Business Technologies is requesting two years to complete this due to required contracting and construction.

1.3 **Assess Secondary Airport Data Center (Business Technologies)** – After implementing Recommendation 1.2, Denver International Airport should perform an evaluation to determine if its secondary data center should be relocated or augmented.

   **Agency Response:** Agree, Implementation Date – April 1, 2021

   **Agency Narrative:** We agree with this recommendation.

1.4 **Develop Data Center Inventory Report (Technology Services)** – The Technology Services agency should develop, as soon as possible, a readily available, easy-to-run report that provides a complete and accurate inventory of all data center hardware, software applications, databases, and underlying equipment.

   **Agency Response:** Agree, Implementation Date – June 2019

   **Agency Narrative:** Technology Services agrees with the finding. We will develop a report that provides a complete and accurate inventory of all data center hardware, software applications, databases, and underlying equipment.

1.5 **Perform Periodic Review of Inventory (Technology Services)** – The Technology Services agency should develop as soon as possible a process to periodically assess the completeness and accuracy of data center inventory.

   **Agency Response:** Agree, Implementation Date – June 2019

   **Agency Narrative:** Technology Services agrees with the finding. We will assess the completeness and accuracy of data center inventory on a semiannual basis.
2.1 **Perform Periodic Application Review (Technology Services)** – Working with the Mayor’s Office, the Technology Services agency should enhance their existing process, as soon as possible, for reviewing the business justification and appropriateness of software applications. This review process should occur at least every three to five years, include all applications, and be done in consultation with application owners.

**Agency Response: Agree, Implementation Date – December 2019**

Agency Narrative: Technology Services agrees with the finding. We will implement an application review process to assess the application risks. The review frequency will be determined by the criticality of the applications.

2.2 **Perform Periodic Application Review (Business Technologies)** – The Denver International Airport’s Business Technologies Division should enhance their existing process, as soon as possible, for reviewing the business justification and appropriateness of software applications. This review process should occur at least every three to five years, include all applications, and be done in consultation with application owners.

**Agency Response: Agree, Implementation Date – September 1, 2019**

Agency Narrative: We agree with this recommendation. DEN Business Technologies will enhance our process to ensure that reviews are being scheduled and completed for applications in the Business Technologies portfolio.

2.3 **Track Data Center Costs (Technology Services)** – The Technology Services agency should track costs associated with providing data center support. These tracked costs should include:

- Personnel costs – including salaries and benefits;
- Building costs – including utilities, insurance and other direct facility costs;
- IT infrastructure costs – including hardware and supporting software, such as operating systems costs; and
- Application-specific costs – including licensing, specific hardware needs, and maintenance costs.

**Agency Response: Agree, Implementation Date – December 2019**

Agency Narrative: Technology Services agrees with the finding. We will track the costs associated with data center support, whenever possible.

2.4 **Track Data Center Costs (Business Technologies)** – The Denver International Airport’s Business Technologies Division should track costs associated with providing data center support. These tracked costs should include:

- Personnel costs – including salaries and benefits;
- Building costs – including utilities, insurance and other direct facility costs;
- IT infrastructure costs – including hardware and supporting software, such as operating systems costs; and
• Application-specific costs – including licensing, specific hardware needs, and maintenance costs.

Agency Response: Agree, Implementation Date – May 1, 2019

Agency Narrative: We agree with this recommendation and will continue to enhance our ability to track costs associated with data center services and support.

2.5 Collaborate to Share Tools and Knowledge – The City’s Technology Services agency and the airport’s Business Technologies Division should share knowledge, tools, and the technology they use to manage their data centers. These combined tools should provide the equivalent of a data center infrastructure management tool set.

Agency Response: Agree, Implementation Date – May 1, 2019 (Business Technologies); June 2019 (Technology Services)

Agency Narratives:

• Business Technologies: We agree with this recommendation. DEN Business Technologies will meet with the Technology Services agency to share the knowledge, tools, and technologies utilized to manage data centers.

• Technology Services: Technology Services agrees with the finding. We will meet with the airport’s Business Technologies Department annually to share the knowledge and experiences of data center management tools.

2.6 Track Energy Use (Technology Services) – The City’s Technology Services agency should set up a process as soon as possible to track, at a minimum, total energy costs for each data center. In the long term, the agency should perform an analysis of energy costs down to the device-level starting in 2020.

Agency Response: Agree, Implementation Date – December 2019

Agency Narrative: Technology Services agrees with the finding.

2.7 Track Energy Use (Business Technologies) – The Denver International Airport’s Business Technologies Division should set up a process as soon as possible to track, at a minimum, total energy costs for each data center. In the long term, the division should perform an analysis of energy costs down to the device-level for each data center starting in 2020.

Agency Response: Agree, Implementation Date – May 1, 2019

Agency Narrative: We agree with this recommendation. DEN Business Technologies will implement a process to track total energy costs for each data center. DEN Business Technologies will perform a cost benefit analysis to determine the feasibility of tracking data center energy costs to the device level.
3.1 **Adopt Data Center Standards (Technology Services)** – The Technology Services agency should adopt, as soon as possible, a set of comprehensive data center operating standards, such as the Telecommunications Industry Association’s standard for data center quality, called “TIA 942.”

**Agency Response: Agree, Implementation Date – December 2019**

Agency Narrative: Technology Services agrees with the finding. We will adopt a data center operating standard that meets the business needs and industrial benchmarks.

3.2 **Update Existing Policies** – The Technology Services agency should work with the General Services Department to update, as soon as possible, the existing IT asset management policy related to problem management and maintenance. This updated policy should be based on the National Institute of Standards and Technology’s standard 800-53 and should address environmental and security control considerations, periodic testing, and problem resolution.

**Agency Response: Agree, Implementation Date – December 2019**

Agency Narratives:

- **Technology Services**: Technology Services agrees with the finding. We will work with General Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.
- **General Services**: General Services agrees with the finding. We will work with Technology Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.

3.3 **Create Procedures** – After implementing Recommendation 3.2, the Technology Services agency should work with the General Services Department to create procedures related to data center maintenance and problem management.

**Agency Response: Agree, Implementation Date – December 2019**

Agency Narratives:

- **Technology Services**: Technology Services agrees with the finding. We will work General Services [sic] to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.
- **General Services**: General Services agrees with the finding. We will work with Technology Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.

3.4 **Prevent and Detect Unauthorized Changes to Systems (Technology Services)** – As soon as possible, leadership of the Technology Services agency should issue a firm directive to agency personnel that no unauthorized changes to systems occur.

**Agency Response: Agree, Implementation Date – June 2019**
Agency Narrative: Technology Services agrees with the finding. We will implement the following controls to prevent and detect the unauthorized changes:

1. Change Management Administrator will conduct periodic change management training and include the policy review in the training.
2. Technology Services leadership team will reiterate the importance of policy adherence to agency personnel.
3. Change Management Administrator will conduct periodic compliance review to detect the unauthorized changes. All identified unauthorized changes will be documented and communicated to the direct supervisors.

3.5 Update Continuity of Operations Plans (Business Technologies) – The Denver International Airport’s Business Technologies Division should work with Denver International Airport’s COOP (continuity of operations planning) administrator to create an annual process to review and approve continuity of operations plans for its data centers.

Agency Response: Agree, Implementation Date – May 1, 2019

Agency Narrative: We agree with this recommendation. DEN Business Technologies will include the data center continuity of operations plans in the DEN COOP.
January 10, 2019

Auditor Timothy M. O’Brien, CPA
Office of the Auditor
City and County of Denver
201 West Colfax Avenue, Dept. 705
Denver, Colorado 80202

Dear Mr. O’Brien,

The Office of the Auditor has conducted a performance audit of Data Centers.

This memorandum provides a written response for each reportable condition noted in the Auditor’s Report final draft that was sent to us on December 18, 2018. This response complies with Section 20-276 (c) of the Denver Revised Municipal Code (D.R.M.C.).

AUDIT FINDING 1
Data Center Infrastructure Cannot Easily Adapt to Changes in Operations

<table>
<thead>
<tr>
<th>RECOMMENDATION 1.1</th>
<th>The Technology Services agency should complete the replacement of its secondary data center with suitable location.</th>
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<tbody>
<tr>
<td>Agree or Disagree with Recommendation</td>
<td>Target date to complete implementation activities (Generally expected within 60 to 90 days)</td>
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</tbody>
</table>
| Agree | December 2019 | Chris Todd
Chief Technology Officer
303-243-4113 |

Narrative for Recommendation 1.1

Technology Services agrees with the finding. We will continue replacing the secondary data center.
RECOMMENDATION 1.4
The Technology Services agency should develop, as soon as possible, a readily available, easy-to-run report that provides a complete and accurate inventory of all data center hardware, software applications, databases, and underlying equipment.

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</tr>
</thead>
</table>
| Agree                                 | June 2019                                                                         | Julie Sutton  
Information Security Manager  
720-913-4964 |

Narrative for Recommendation 1.4
Technology Services agrees with the finding. We will develop a report that provides a complete and accurate inventory of all data center hardware, software applications, databases, and underlying equipment.

RECOMMENDATION 1.5
The Technology Services agency should develop as soon as possible a process to periodically assess the completeness and accuracy of data center inventory.

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</thead>
</table>
| Agree                                 | June 2019                                                                         | Chris Hagan  
Data Center Manager  
720-913-5261 |

Narrative for Recommendation 1.5
Technology Services agrees with the finding. We will assess the completeness and accuracy of data center inventory on a semiannual basis.
AUDIT FINDING 2
Data Center Operations Lack Application Reviews, Cost Data, and Collaboration Between Technology Services and Business Technologies

RECOMMENDATION 2.1
Working with the Mayor’s Office, the Technology Services agency should enhance their existing process, as soon as possible, for reviewing the business justification and appropriateness of software applications. This review process should occur at least every three to five years, include all applications, and be done in consultation with application owners.

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<tr>
<td>Agree</td>
<td>December 2019</td>
<td>Chad Mitchell Executive Director of Application Services 720-913-4953</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 2.1
Technology Services agrees with the finding. We will implement an application review process to assess the application risks. The review frequency will be determined by the criticality of the applications.

RECOMMENDATION 2.3
The Technology Services agency should track costs associated with providing data center support. These tracked costs should include:
• Personnel costs – including salaries and benefits;
• Building costs – including utilities, insurance and other direct facility costs;
• IT infrastructure costs – including hardware and supporting software, such as operating systems costs; and
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<td>Agree</td>
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<td>Chris Todd Chief Technology Officer 303-243-4113</td>
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Narrative for Recommendation 2.3
Technology Services agrees with the finding. We will track the costs associated with data center support, whenever possible.
**RECOMMENDATION 2.5**
The City’s Technology Services agency and the airport’s Business Technologies Department should share knowledge, tools, and the technology they use to manage their data centers. These combined tools should provide the equivalent of a data center infrastructure management tool set.

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<td>Chris Hagan&lt;br&gt;Data Center Manager&lt;br&gt;720-913-5261</td>
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**Narrative for Recommendation 2.5**
Technology Services agrees with the finding. We will meet with the airport’s Business Technologies Department annually to share the knowledge and experiences of data center management tools.

**RECOMMENDATION 2.6**
The City’s Technology Services agency should set up a process as soon as possible to track, at a minimum, total energy costs for each data center. In the long term, the agency should perform an analysis of energy costs down to the device-level starting in 2020.

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**Narrative for Recommendation 2.6**
Technology Services agrees with the finding.
AUDIT FINDING 3
Technology Services and the Airport Should Employ Consistent Operational Standards at All Data Center Locations

RECOMMENDATION 3.1
The Technology Services agency should adopt, as soon as possible, a set of comprehensive data center operating standards, such as the Telecommunications Industry Association’s standard for data center quality, called “TIA 942.”

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</table>
| Agree                                | December 2019                                                                          | Chris Hagan  
Data Center Manager  
720-913-5261                                                        |

Narrative for Recommendation 3.1
Technology Services agrees with the finding. We will adopt a data center operating standard that meets the business needs and industrial benchmarks.

RECOMMENDATION 3.2 – Technology Services
The Technology Services agency should work with the General Services Department to update, as soon as possible, the existing IT asset management policy related to problem management and maintenance. This updated policy should be based on the National Institute of Standards and Technology’s standard 800-53 and should address environmental and security control considerations, periodic testing, and problem resolution.

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| Agree                                | December 2019                                                                          | Chris Hagan  
Data Center Manager  
720-913-5261                                                        |

Narrative for Recommendation 3.2
Technology Services agrees with the finding. We will work with General Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.
RECOMMENDATION 3.2 – General Services
The Technology Services agency should work with the General Services Department to update, as soon as possible, the existing IT asset management policy related to problem management and maintenance. This updated policy should be based on the National Institute of Standards and Technology’s standard 800-53 and should address environmental and security control considerations, periodic testing, and problem resolution.

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<td>Agree</td>
<td>December 2019</td>
<td>Kevin O’Neil&lt;br&gt;Interim Director of Facilities Management&lt;br&gt;720-865-7512</td>
</tr>
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Narrative for Recommendation 3.2
General Services agrees with the finding. We will work with Technology Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.

RECOMMENDATION 3.3 – Technology Services
After implementing Recommendation 3.2, the Technology Services agency should work with the General Services Department to create procedures related to data center maintenance and problem management.

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Narrative for Recommendation 3.3
Technology Services agrees with the finding. We will work General Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.
RECOMMENDATION 3.3 – General Services
After implementing Recommendation 3.2, the Technology Services agency should work with the General Services Department to create procedures related to data center maintenance and problem management.

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| Agree                                | December 2019                                                                   | Kevin O’Neil  
Interim Director of Facilities Management  
720-865-7512 |

Narrative for Recommendation 3.3
General Services agrees with the finding. We will work with Technology Services to update the policy and procedure to document the environmental and security control considerations, periodic testing, and problem resolution.

RECOMMENDATION 3.4
As soon as possible, leadership of the Technology Services agency should issue a firm directive to agency personnel that no unauthorized changes to systems occur.

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| Agree                                | June 2019                                                                       | Julia Matrose  
Change Management Administrator  
720-913-4141 |

Narrative for Recommendation 3.4
Technology Services agrees with the finding. We will implement the following controls to prevent and detect the unauthorized changes:
1. Change Management Administrator will conduct periodic change management training and include the policy review in the training
2. Technology Services leadership team will reiterate the importance of policy adherence to agency personnel.
3. Change Management Administrator will conduct periodic compliance review to detect the unauthorized changes. All identified unauthorized changes will be documented and communicated to the direct supervisors.
Please contact Samantha Shih at 720-913-5485 with any questions.

Sincerely,

David Edinger
Chief Information Officer

cc: Valerie Walling, Deputy Auditor, CPA, CMC®
Kevin Sear, CPA, CIA, CISA, CFE, CGMA, Audit Manager
Christine Binnicker, Deputy Chief Information Officer
Christopher Todd, Chief Technology Officer
Kyle Winders, Information Technology Director
Chris Hagan, Data Center Manager
January 10, 2019

Auditor Timothy M. O’Brien, CPA
Office of the Auditor
City and County of Denver
201 West Colfax Avenue, Dept. 705
Denver, Colorado 80202

Dear Mr. O’Brien,

The Office of the Auditor has conducted a performance audit of Data Centers.

This memorandum provides a written response for each reportable condition noted in the Auditor’s Report final draft that was sent to us on December 18, 2018. This response complies with Section 20-276 (c) of the Denver Revised Municipal Code (D.R.M.C.).

AUDIT FINDING 1
Data Center Infrastructure Cannot Easily Adapt to Changes in Operations

<table>
<thead>
<tr>
<th>RECOMMENDATION 1.2</th>
<th>Denver International Airport should continue implementing a more robust internet service solution as soon as possible.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree or Disagree with Recommendation</td>
<td>Target date to complete implementation activities (Generally expected within 60 to 90 days)</td>
</tr>
<tr>
<td>Agree</td>
<td>December 31, 2020</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 1.2
We agree with this recommendation. DEN Business Technologies is requesting two years to complete this due to required contracting and construction.
RECOMMENDATION 1.3
After implementing Recommendation 1.2, Denver International Airport should perform an evaluation to determine if its secondary data center should be relocated or augmented.

<table>
<thead>
<tr>
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<th>Target date to complete implementation activities (Generally expected within 60 to 90 days)</th>
<th>Name and phone number of specific point of contact for implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>April 1, 2021</td>
<td>Tim Coogan</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 1.3
We agree with this recommendation.

AUDIT FINDING 2
Data Center Operations Lack Application Reviews, Cost Data, and Collaboration Between Technology Services and Business Technologies

RECOMMENDATION 2.2
The Denver International Airport’s Business Technologies Division should enhance their existing process, as soon as possible, for reviewing the business justification and appropriateness of software applications. This review process should occur at least every three to five years, include all applications, and be done in consultation with application owners.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>September 1, 2019</td>
<td>Tim Coogan</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 2.2
We agree with this recommendation. DEN Business Technologies will enhance our process to ensure that reviews are being scheduled and completed for applications in the Business Technologies portfolio.
RECOMMENDATION 2.4
The Denver International Airport’s Business Technologies Division should track costs associated with providing data center support. These tracked costs should include:
- Personnel costs – including salaries and benefits;
- Building costs – including utilities, insurance and other direct facility costs;
- IT infrastructure costs – including hardware and supporting software, such as operating systems costs; and
- Application-specific costs – including licensing, specific hardware needs, and maintenance costs.

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</thead>
<tbody>
<tr>
<td>Agree</td>
<td>May 1, 2019</td>
<td>Tim Coogan</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 2.4
We agree with this recommendation and will continue to enhance our ability to track costs associated with data center services and support.

RECOMMENDATION 2.5
The City’s Technology Services agency and the Denver International Airport’s Business Technologies Division should share knowledge, tools, and the technology they use to manage their data centers. These combined tools should provide the equivalent of a data center infrastructure management tool set.

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</thead>
<tbody>
<tr>
<td>Agree</td>
<td>May 1, 2019</td>
<td>Tim Coogan</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 2.5
We agree with this recommendation. DEN Business Technologies will meet with the Technology Services agency to share the knowledge, tools, and technologies utilized to manage data centers.
RECOMMENDATION 2.7
The Denver International Airport’s Business Technologies Division should set up a process as soon as possible to track, at a minimum, total energy costs for each data center. In the long term, the division should create a plan to track data center energy costs down to the device-level starting with the 2020 budget cycle.

<table>
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<tbody>
<tr>
<td>Agree</td>
<td>May 1, 2019</td>
<td>Tim Coogan</td>
</tr>
</tbody>
</table>

Narrative for Recommendation 2.7
We agree with this recommendation. DEN Business Technologies will implement a process to track total energy costs for each data center. DEN Business Technologies will perform a cost benefit analysis to determine the feasibility of tracking data center energy costs to the device level.

AUDIT FINDING 3
Technology Services and the Airport Should Employ Consistent Operational Standards at All Data Center Locations

RECOMMENDATION 3.5
The Denver International Airport’s Business Technologies Division should work with Denver International Airport’s COOP administrator to create an annual process to review and approve continuity of operations plans for its data centers.

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Agree</td>
<td>5/1/2019</td>
<td>Tim Coogan</td>
</tr>
</tbody>
</table>
Narrative for Recommendation 3.5
We agree with this recommendation. DEN Business Technologies will include the data center continuity of operations plans in the DEN COOP.

Please contact Tim Coogan at 303-342-4741 with any questions.

Sincerely,

[Signature]
Robert W. Kastelitz
SVP, Chief Information Officer

cc: Kim Day, Chief Executive Officer
Gisela Shanahan, EVP, Chief Financial Officer
Chris Larivee, Senior Director
Tim Coogan, Chief Information Security Officer
Valerie Walling, Deputy Auditor, CPA, CMC®
Kevin Sear, CPA, CIA, CISA, CFE, CGMA, Audit Manager
OBJECTIVE

This audit evaluated the two data centers operated by the City and County of Denver’s Technology Services agency and the two data centers serving the Denver International Airport. The data centers were assessed for efficiency and effectiveness of operations against applicable standards to ensure the security and the operability of technology assets, such as equipment, facilities, and infrastructure.

SCOPE

The scope of the audit was limited to primary and secondary data centers for the City’s Technology Services agency and for Denver International Airport’s Business Technologies Division for the period of operation from August 2018 to December 2018. The City’s General Services Department was also included in this audit because it provides facility support, including maintenance and operation of City facilities that support the two Technology Services data centers audited. Data centers maintained or managed by other agencies or by cloud-service providers were not included.

METHODOLOGY

We applied multiple methodologies to gather and analyze information related to the audit objective. These included:

- Interviewing key personnel within the City and County of Denver’s Technology Services agency and General Services Department and within Denver International Airport’s Business Technologies Division and Airport Security Section.
- Observing physical and environmental controls during walk-throughs of the primary and secondary data centers for the Technology Services agency and for Denver International Airport.
- Observing and evaluating environmental controls and preventative maintenance programs.
- Reviewing vendor contracts for schedules of preventative maintenance.
- Reviewing data center network drawings, architectural plans, and inventory reports.
- Reviewing reporting metrics and key performance indicators.
- Reviewing data center financial information.
- Surveying data center management to determine adherence to Telecommunications Industry Association’s TIA-942 standard—including those sections applicable to telecommunications, electrical, mechanical, and architectural data center elements.
APPENDICES

Appendix A – Glossary

Application – A software product that was developed to provide services and/or functionality to a user.

- Enterprise application – A software product that an organization uses to provide solutions for larger-scale requirements. Enterprise applications provide services that are used throughout an organization instead of meeting the requirements for a single department. For example, all employees may need access to an enterprise application system to manage time-off requests, review pay information, or select benefits.

Application owner – Typically the department in an organization that is responsible for an application. The application owner understands the specific requirements for functionality, data gathering and retention, and reporting.

Availability – A system being operational and ready to provide computing services when required.

Bandwidth – The limit of the transmission channel that can handle the throughput of data.

Biometric locks – Locks that grant access based on a unique body trait of the person trying to open it, such as a retina- or fingerprint-scanner.

Blade servers – A stripped-down computer that creates a very small profile system, which can serve as an independent server.

Computing devices – Devices that include three main components: the central processing unit, or CPU; random access memory, or RAM; and data storage devices, such as hard drives.

Decommissioning – The process of removing computer equipment or software applications from service.

Downtime – The amount of time that a data center or computer server is unavailable for use.

Firewall – A system designed to prevent unauthorized access to or from a private network.

Key card – A plastic card used instead of a door key that bears magnetically encoded data, which can be read and processed by an electronic device.

Mainframe – A large computer that is typically used for mission-critical applications, which require extensive data-processing.

Mantrap – A small room with an entry door on one wall and an exit door on the opposite wall. Mantraps are most often used in physical security to separate non-secure areas from secure areas and prevent unauthorized access.

Network devices – The physical devices that control computer network activity, such as routers.

Network switch – A computer networking device that connects devices together on a computer.
network by identifying where data should go in order to receive, process, and forward that data to the destination device. These are also called “switching hubs,” “bridging hubs,” or officially a “MAC bridge.”

**Operational resilience** – The ability of an organization to continue to operate even when faced with disruption to its environment. Developing and practicing plans and techniques enables resilience.

**Patch** – Software code that contains changes to a computer program or operating system and fixes security vulnerabilities or improves the performance of that application or operating system.

**Router** – A hardware device that quite literally routes data from a local area network to another network connection. A router acts like a coin-sorting machine, allowing only authorized machines to connect to other computer systems.

**Server** – A computer that provides data to other computers.

- **Virtual server** – A computer server that supports more than one application or operating system instead of being dedicated for a single application. Virtual servers allow for efficiency by creating a large, shared virtual environment that allows previously unused computing resources to be allocated to another application. Because one virtual server can provide services that previously required multiple servers, it provides cost-savings for equipment and cooling and allows for more efficient use of data center space.

**Stranded infrastructure** – Equipment or computing processing power that cannot be used based on the design or configuration of the system.

**Uptime** – A measure of the reliability of a system or data center, based on the percentage of time the system is working and available.
Office of the Auditor

The Auditor of the City and County of Denver is independently elected by the citizens of Denver. He is responsible for examining and evaluating the operations of City agencies and contractors for the purpose of ensuring the proper and efficient use of City resources. He also provides other audit services and information to City Council, the Mayor, and the public to improve all aspects of Denver’s government.

The Audit Committee is chaired by the Auditor and consists of seven members. The Audit Committee assists the Auditor in his oversight responsibilities regarding the integrity of the City’s finances and operations, including the reliability of the City’s financial statements. The Audit Committee is structured in a manner that ensures the independent oversight of City operations, thereby enhancing citizen confidence and avoiding any appearance of a conflict of interest.

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Denver CO, 80202
(720) 913-5000 ♦ Fax (720) 913-5253
www.denverauditor.org

Our Mission

We deliver independent, transparent, and professional oversight in order to safeguard and improve the public’s investment in the City of Denver. Our work is performed on behalf of everyone who cares about the City, including its residents, workers, and decision-makers.