

SPECIAL ANALYSIS

Audit Analytics Capabilities and New Directions in the Denver Auditor's Office

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AUDITOR'S LETTER

June 23, 2022

We surveyed other local government audit organizations and reviewed professional literature about audit analytics with two objectives:

- To assess the current state of audit analytics methods, tools, and applications to auditing.
- To identify areas where we can further enhance how we use analytics to improve our audit work.

I am pleased to present the results of this effort.

Our comparative study found the Denver Auditor's Office is a leader in its use of and reporting on audit analytics. From the over 100 local government audit organizations that responded to our survey, we learned our office is among the few local government audit organizations that apply advanced analytics to identify risks and assess controls of critical city systems and processes.

This is because we have a dedicated analytics team, collaboration among our audit staff, ongoing training, and new tools for working with large datasets and statistics. We also found our analytics work is often more rigorous or extensive than the audit analytics methods described in professional literature.

Meanwhile, we found that we report our analytical results in more ways than most other local government audit organizations. We share our results internally to support our audit work, publicly in reports to the Independent Audit Committee twice a year, and with individual city agencies after each analytics project.

From our peers in local government auditing, we learned of new ways to enhance our audit analytics program, such as applying new techniques to identify data-quality issues. The academic literature also gave us new ideas on how we can use statistics to improve our risk assessment processes.

We thank the Association of Local Government Auditors for its partnership in making our survey possible, and we thank the audit organizations who provided responses. Additionally, I appreciate the past and present members of our Audit Analytics Team, whose efforts have helped advance our audit analytics program these last five years.

Please contact me at 720-913-5000 with any questions.

Denver Auditor's Office

A handwritten signature in black ink, appearing to read "Timothy M. O'Brien".

Timothy M. O'Brien, CPA
Auditor

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BACKGROUND

Continuous Auditing and Audit Analytics

Audit analytics is the next evolution in auditing and is a reaction to the vast amount of digital information available today.

The Denver Auditor’s Office began its audit analytics program in 2017 by implementing continuous auditing — a practice that involves automating specific steps to audit digital information soon after it is created.¹

Continuous auditing generally emerged in the late 1990s and uses auditing software that connects to an organization’s financial systems. In its infancy, continuous auditing was revolutionary in that it increased auditors’ efficiency. It allowed auditors to examine entire sets of data rather than only samples, and it reduced the time between when an event happens and when auditors could review the event.

Audit analytics is the next evolution in auditing and is a reaction to the vast amount of digital information available today. Organizations are digitizing their processes and accepting information from internet-connected devices, such as smartphones submitting requests to Denver’s 311 system. For auditors to be successful in auditing their organizations, they need to be able to examine large amounts of data securely, quickly, and effectively.

Therefore, audit analytics differs from simply using audit software to automate more traditional audit tasks. Audit analytics:

- Applies advanced statistics and data science tools.
- Applies expertise to examine large datasets that describe an organization’s transactions and functions.
- Helps identify inefficiencies, fraud, or data-quality problems.²
- Helps identify the causes and effects of issues.

Both the public and private sectors recognize the importance of audit analytics as a necessary skill for auditors and as a critical technique in auditing. For example, the U.S. Government Accountability Office launched its own analytics program, and large public accounting firms frequently write about the need for analytics in the audit profession.³

Our own recent survey, described in this report, found local government audit organizations across the United States and Canada are also applying analytics.

After more than four years of growth and innovation in the Denver Auditor’s Office, we wanted to take a deeper look at our capabilities in

¹ Zabihollah Rezaee, Ahmad Sharbatoghlie, Rick Elam, and Peter L. McMickle, “Continuous Auditing: Building Automated Auditing Capability,” *AUDITING: A Journal of Practice & Theory*, no 1 (2002): 147-163.

² Helen Brown-Liburd, Hussein Issa, and Danielle Lombardi, “Behavioral Implications of Big Data’s Impact on Audit Judgment and Decision Making and Future Research Directions,” *Accounting Horizons* 29, no. 2 (2015): 451-468.

³ See [Appendix C](#) for complete citations of the sources cited.

audit analytics and continuous auditing to identify strengths and new opportunities.

To assess this, we:

1. Surveyed fellow members of the Association of Local Government Auditors about how they use and report audit analytics.
2. Reviewed literature from various professional sources — such as the American Institute of Certified Public Accountants, The Institute of Internal Auditors, and relevant books and peer-reviewed journals, such as Accounting Horizons and the Journal of Emerging Technologies in Accounting.

Our survey gave us a snapshot of where our office is with respect to other local government audit organizations and specifically where we stand in our peer group — those local government audit organizations in the U.S. and Canada with 26 or more auditors. The literature review then gave us an idea of leading techniques and current research in the field of audit analytics.

Combined, these sources give us a broader understanding of the current state of audit analytics and how new technologies and digitized governments are advancing their practices. By comparing what we learned with our own use of analytics, we can clearly see where the Denver Auditor's Office is and how we can continue improving.

ABOUT OUR SURVEY METHODS

In fall 2021, we sent a survey to 273 members of the Association of Local Government Auditors, a professional organization that seeks to advance the local government auditing profession in both the U.S. and Canada.

Of those 273 member organizations, 107 either fully or partially completed our survey — a participation rate of about 39%. See [Appendix A](#) for more information about our survey methods.

Origins of Our Audit Analytics Program

When we started our audit analytics program in 2017, we began with continuous auditing and used a pilot project to test our technical infrastructure and develop internal processes. That project focused on identifying city contracts that appeared to be designed to avoid City Council oversight.

We developed automated scripts — sets of commands carried out by a piece of software — to sort through thousands of contracts and find those that appeared to be either:

- Written for a few thousand dollars shy of the \$500,000 threshold that triggers a City Council vote.
- Split to evade oversight — such as two or more contracts between the same vendor and the same city agency that were each for less than \$500,000, but when combined, would be over the

threshold for City Council review.

To accomplish this, we connected our audit software to a city data system and then wrote scripts to evaluate contract values and generate a list of contracts that met our criteria. We used an audit software that allowed us to set a schedule for automatically running scripts at regular intervals.

This initial process gave us many insights into how analytics can be used in local government auditing, how we could work with data limitations and use additional audit work to validate results from our analytics, and how we could incorporate data-based insights into our risk assessment process. For example, an audit that used results from our risk criteria found that most contracts we had flagged as potentially inappropriate had legitimate reasons to be divided and, therefore, our analytics had what is called a high “false-positive rate.” From this, we learned of some limitations in data analytics and began developing ways to reduce false positives.

Our Audit Analytics Program Today

In the years since our first continuous audit project, our audit analytics team evolved from one staff member to a team of five dedicated staff members as of early 2022. At times, other auditors in our office also join the team’s projects to build their skills and provide their subject-matter expertise to the team’s analyses.

We have also expanded the tools and approaches we use for analyzing data and automating our work. When we started, we used:

- Arbutus, an audit software with the ability to connect to some datasets and automate analyses with scripts.
- STATA, a statistics software used to describe values within datasets and look at relationships between variables.

Now, we also use Python — a more sophisticated computer language — to connect additional data sources, automate advanced analyses and statistics, and visualize results.

Together, these tools allow us to efficiently and securely connect to a wide range of data sources, look for control issues or risks within large datasets, and automate those analyses to improve our efficiency and the timeliness of identifying any potential issues.

“Controls” are safeguards — like a policy, procedure, or plan — meant to ensure a process is followed correctly. In auditing, a control test looks for evidence to determine whether a control is working.

“Risk” is a broad term we use to describe a potential event that may have a negative effect. Government auditors consider a broad range of risks including waste, inefficiencies, misuse, abuse, and fraud with respect to how tax dollars are used.

An example of a risk we use our software to identify is whether any separation-of-duties violations exist within the city's tax write-off process. Our scripts determine whether the person who requested a tax write-off is the same as the person who approved the tax write-off, which would present a risk.

Our work has been informed by training presentations and conversations at audit conferences, other auditors' published analytics work, peer-reviewed journals, and information from professional associations such as The Institute of Internal Auditors, the Association of International Certified Professional Accountants, and the Association of Certified Fraud Examiners.

RESULTS

The Denver Auditor's Office Is a Leader in Data Analytics in Local Government Auditing, with Room to Grow

The Denver Auditor's Office is generally among the leaders in using audit analytics when compared to our peer organizations in local government auditing, and our analytical techniques are often ahead of the curve of the methods described in recent academic and professional literature.

Specifically, we excel in:

- Having dedicated audit analytics resources, both in staff expertise and technology.
- Continuous auditing — including using analytics to find outliers or conditions that could indicate a process or system is not working as it should (i.e., risk assessments and control tests).
- Using statistics and methods to fine-tune how sensitive our analytics are in identifying risks within a dataset, with the goal of reducing the number of false-positive results.
- Applying analytics and continuous auditing for general risk assessment and annual planning.
- Applying analytics to specific audits and using analytics to identify the cause of an issue.
- Reporting analytical results in myriad ways — such as through original audits and follow-up audits, summary reports to city agencies and the public, and detailed audit work papers.

In particular, our survey of local government audit organizations and our review of relevant professional literature bolstered our understanding of the importance of having an audit analytics program in the Denver Auditor's Office.

We found that audit organizations that have dedicated resources, like ours, are more likely to use analytics on a regular basis and they are more likely to apply the types of techniques recommended in professional literature.

We also learned of areas where the Denver Auditor's Office can expand our analytics and learn from our peers in local government auditing and academia.

For example, our survey results found several peer audit organizations use analytics in ways we are not yet — such as:

- Using certain advanced statistical techniques like clustering, which is a way to find similar and dissimilar data entries, and using statistics

to compare values to assist in finding data-reliability issues.⁴

- Using technologies to alert auditors when an automated analytic identified an issue.

Some techniques published in the literature are also new to us. These include:

- Applying statistical techniques to find patterns and tools to read contract language that could expand how we find risks in the City and County of Denver's operations, such as identifying bid-rigging or assessing contract compliance.
- Implementing a new process in the planning phase of our projects to streamline how we identify opportunities for new analytics to detect problems.⁵

By focusing on these areas, we can expand how we look for risks, improve the efficiency of our Audit Analytics Team, and improve how our analytics can ultimately benefit the City and County of Denver.

Denver's Audit Analytics Practices Align with Recent Research and Can Adopt New Techniques

Various research highlights how audit analytics is increasingly important and expected in both internal and external audit functions. For example:

- A 2014 survey of 402 internal auditors from private firms that use major auditing software showed few firms had implemented the audit analytics tools academics recommend, such as data mining and clustering. However, the survey also found that internal audit departments with technical competency are more likely to frequently use audit analytics.⁶
- A 2016 survey of over 350 external auditors in Canada showed clients, on average, expect audit analytics to be used and that the use of analytics improves auditors' confidence in their conclusions.⁷
- A 2020 survey of over 100 managers and partners at major accounting firms in Norway underscored that audit analytics is becoming preferred to traditional audit tools and that analytics is an acceptable, effective approach to identifying risk and completing substantive testing.⁸

⁴ "Clustering" is a statistical analysis that groups similar records based on many different factors. When looking for data-quality issues, a record that does not group — or cluster — with other records may be problematic. In general, this technique can help auditors find odd records in large datasets.

⁵ Won Gyun No, Kyungha (Kari) Lee, Feiqi Huang, and Qiao Li, "Multidimensional Audit Data Selection (MADS): A Framework for Using Data Analytics in the Audit Data Selection Process," *Accounting Horizons* 33, no. 3 (2019): 127-140.

⁶ He Li, Jun Dai, Tatiana Gershberg, and Miklos A. Vasarhelyi, "Understanding Usage and Value of Audit Analytics for Internal Auditors: An Organizational Approach," *International Journal of Accounting Information Systems*, 28 (2018): 59-76.

⁷ Clark Hampton and Theophanis C. Stratopoulos, "Audit Data Analytics Use: An Exploratory Analysis" (2016), available via SSRN, accessed Feb. 22, 2022, <https://ssrn.com/abstract=2877358>, 27.

⁸ Aasmund Eilifsen, Finn Kinserdal, William F. Messier Jr., and Thomas E. McKee, "An Exploratory Study into the Use of Audit Data Analytics on Audit Engagements," *Accounting Horizons*, no. 4 (2020): 75-103.

These firms are using analytics across a range of datasets, from general ledgers to inventories and salaries. This 2020 survey also highlighted how routine it is for audit professionals to complete analytics work using a mix of technology — beginning with acquiring and preparing data for analysis and ending with analysis and testing.

- A 2021 study found accounting faculty members at several universities want more analytics training in their curriculums — from basic subjects, like Microsoft Excel, to advanced topics such as artificial intelligence.⁹

Auditors must learn to use analytical tools that can mine information, identify risks, and conduct complex testing.

Meanwhile, in 2019, a series of articles published in the journal *Accounting Horizons* gave specific examples of how and why the field of auditing is turning more toward analytics and of the need for auditors to learn those skills.¹⁰

Indeed, what used to be a discussion of how computer-assisted audit tools can help find duplicates or missing values has now moved into how auditors must learn to use analytical tools that can mine information, identify risks, and conduct complex testing.

As organizations move toward fully digitized financial and business processes, auditors must follow.

Considering this transition to a digital world, one group of researchers argues that using audit analytics — specifically continuous auditing — is one way audit organizations can both follow audit standards and conduct risk-based audit planning.¹¹

While some articles simply discuss the potential benefits of applying emerging technologies, we found many excellent examples and step-by-step guides showing how we could apply new audit analytics to our own toolkit in the Denver Auditor's Office.¹²

Ahead of the Curve

Our intentional focus on audit analytics since 2017 has yielded an audit analytics and continuous audit program that applies a broad range of

⁹ Ralph S. Polimeni and Jacqueline A. Burke, "Integrating Emerging Accounting Digital Technologies and Analytics into an Undergraduate Accounting Curriculum – A Case Study," *Journal of Emerging Technologies in Accounting* 18, no. 1 (2021): 159-173.

¹⁰ Kogan, Alexander Kogan, Brian W. Mayhew, and Miklos A. Vasarhelyi, "Audit Data Analytics Research – An Application of Design Science Methodology," *Accounting Horizons* 33, no. 3 (2019): 69-73; Alexander Kogan, Brian W. Mayhew, and Miklos A. Vasarhelyi, "Audit Data Analytics Research – An Application of Design Science Methodology," *Accounting Horizons* 33, no. 3 (2019): 69-73; Deniz Appelbaum, Alexander Kogan, and Miklos A. Vasarhelyi, "Big Data and Analytics in the Modern Audit Engagement: Research Needs," *Auditing: A Journal of Practice and Theory* 36, no. 4 (2017): 1-27.

¹¹ "International Standards for the Professional Practice of Internal Auditing," The Institute of Internal Auditors (October 2016), accessed Dec. 27, 2021, <https://na.theiia.org/standards-guidance/Public%20Documents/IPPF-Standards-2017.pdf>; Marc Eulerich, Christine Georgi, and Alexander Schmidt, "Continuous Auditing and Risk-Based Audit Planning – an Empirical Analysis," *Journal of Emerging Technologies in Accounting* 17, no. 2 (2020): 141.

¹² Ting (Sophia) Sun, "Applying Deep Learning to Audit Procedures: An Illustrative Framework," *Accounting Horizons* 33, no. 3 (2019): 89-109; Yan Zhaokai and Kevin C. Moffitt, "Contract Analytics in Auditing," *Accounting Horizons* 33, no. 3 (2019): 111-126.

Many of our own audit analytics approaches are more sophisticated than those examples we saw published in professional literature during the last three years.

analytics tools for risk assessments and control tests on specific audits to examine whether rules are in place to keep a process working as it should. We have also used these tools for organization-level risk assessments that help us develop our annual Audit Plan.

Many of our own audit analytics approaches are more sophisticated than those examples we saw published in professional literature during the last three years.

For example, a method published in the Journal of Emerging Technologies in Accounting describes how to perform risk analytics on a general ledger by identifying certain specifics, such as whether journal entries were entered on a Sunday, evenly divisible by \$1,000, or posted to a cash account.¹³ We apply similar methods but also factor in the time of day an entry was made or whether it was made on a holiday, and we search text fields for keywords that may indicate a potential issue with a transaction.¹⁴

Similarly, in another case study published in the journal Accounting Horizons, researchers used scripts to detect appropriate separation of duties, abnormal values, transactions made at odd times of day, and processes that took abnormal lengths of time.¹⁵

We apply some of the same techniques when examining tax-return processing data and information on who requested and approved tax write-offs in GenTax, the city's tax collection system. Recently, we added another analysis on the data held in GenTax: We compared the location of businesses with late or missing tax payments to where city tax collectors conduct their fieldwork. From this, we identified an opportunity to potentially improve how the city collects overdue taxes.¹⁶

We also use statistical techniques to improve the accuracy and effectiveness of our risk-finding analytics. Through an internal analysis, we found that our approach — of using a broad range of statistical analyses, along with other risk analytics — identifies a higher concentration of transactions that have issues than if we were to randomly sample transactions from among a full set of data.¹⁷

¹³ Lorraine S. Lee, Gretchen Casterella, and Barry Wray, "Preparing for Audit Data Analytics with the AICPA General Ledger Audit Data Standards," Journal of Emerging Technologies in Accounting 18, no. 1 (Spring 2021): 131–57, accessed Feb. 22, 2022, <https://doi.org/10.2308/JETA-2020-022>.

¹⁴ City and County of Denver Auditor's Office, "2020 End-Year Audit Analytics Update" (February 2021), accessed Feb. 22, 2022, https://denvergov.org/files/assets/public/auditor/documents/audit-services/audit-reports/2020/2020-end_year-update_final.pdf, 24.

¹⁵ Tiffany Chiu and Mieke Jans, "Process Mining of Event Logs: A Case Study Evaluating Internal Control Effectiveness," Accounting Horizons 33, no. 3 (2019): 141–156.

¹⁶ City and County of Denver Auditor's Office, "2021 Semi-Annual Audit Analytics Update" (August 2021), accessed Feb. 22, 2022, https://denvergov.org/files/assets/public/auditor/documents/audit-services/audit-reports/2021/continuous-audit-semi-annual_update_2021-final.pdf, 29.

¹⁷ City and County of Denver Auditor's Office, "2020 End-Year Audit Analytics Update" (February 2021), accessed Feb. 22, 2022, https://denvergov.org/files/assets/public/auditor/documents/audit-services/audit-reports/2020/2020-end_year-update_final.pdf, 26.

Areas for Growth

The literature we reviewed did not disappoint in inspiring new ideas for us to continue innovating. For instance, we could make better use of:

- **CLUSTERING** – a statistical technique that uses multiple factors to identify groups of observations that are similar and dissimilar.

Our survey results showed us other local government audit organizations use clustering to find outliers in datasets and to help identify issues in data quality. We also found this tool was suggested as an additional step in analytics-based risk assessments to identify odd transactions.¹⁸

We plan to learn more about how we could apply the clustering technique on the City and County of Denver’s data to find statistically similar and dissimilar observations, which will help us further assess risks.

- **FUZZY LOGIC** – a statistical technique that scores how similar two words or phrases are to each other.

While we have used this technique to look for duplicate transactions between the city’s credit card purchase order systems, an article from the Journal of Emerging Technologies in Accounting showed us a new way to apply fuzzy logic to find potentially fake vendors in a list set up by an accounts payable employee.¹⁹ We can apply this same technique to the vendors in the City and County of Denver’s system to assess the potential for fake vendors.

- **NEURAL NETWORK ANALYSIS** – an artificial intelligence tool that mimics the human brain and can find relationships among large datasets with dozens of variables.

An article in the Journal of Emerging Technologies in Accounting demonstrated this technique on historical data to identify contractors that were likely to receive a penalty from the government.

With the information our office’s Denver Labor team has on city contractors and past payroll violations, we plan to evaluate whether we can use this technique to identify potential payroll violations. This analysis could yield more information for Denver Labor’s investigative work.

- **NATURAL LANGUAGE PROCESSING** – a computer program that analyzes text, which can be used to find contracts that may be problematic.²⁰

Traditionally, reviewing contracts is a time-intensive task. We learned from an article in Accounting Horizons how researchers used natural language processing to find keywords and amounts in many

¹⁸ Won Gyun No, Kyungha (Kari) Lee, Feiqi Huang, and Qiao Li, “Multidimensional Audit Data Selection (MADS): A Framework for Using Data Analytics in the Audit Data Selection Process,” Accounting Horizons 33, no. 3 (2019): 127-140.

¹⁹ Jamie L. Hoelscher and Trevor Shonhiwa, “Not So Fuzzy Auditing Analytics,” Journal of Emerging Technologies in Accounting 18, no. 1 (2021): 99-112.

²⁰ Yan Zhaokai and Kevin C. Moffitt, “Contract Analytics in Auditing,” Accounting Horizons 33, no. 3 (2019): 111-126.

In its most basic form, natural language processing finds keywords in text-based files. More advanced forms can evaluate text for meaning.

contracts. The researchers used these results to compare contracts to a standard template and get a similarity score. A high score indicated a match between the contract and the template, while a low score indicated a mismatch — and therefore, a risky contract.

This kind of analysis can improve auditors' efficiency. In a contract compliance audit, the team could examine only the risky contracts, rather than the entire set of contracts the computer started with.

In its most basic form, natural language processing finds keywords in files containing text (e.g., words in a PDF or email). More advanced forms of this technique can evaluate text for meaning, such as whether a customer review was positive or negative.

Finally, from an article on audit data selection, we learned of another process for developing risk-finding analytics that we can use to strengthen our methods.²¹ While our process for finding risky transactions is similar, there are two steps we can adopt from the article:

- First is an approach for developing new analyses. The article describes a team identifying ways in which a selected process could fail at each step — for example, the process of submitting and then paying an invoice.²² Then, the team could identify whether the data is available to measure each of those failure points.

For example, one thing that could go wrong in the City and County of Denver's expenditure process is that a purchase is completed without prior approval. We could identify this issue by finding any purchase in the system with a payment date that came before an approval date or by finding purchases that are missing an approval record. We would then repeat this process for each additional failure point in the expenditure process.

- Second, once the analytics from step one are created and used to identify a group of potentially risky transactions, the article suggests using clustering as an additional statistical technique to further reduce the number of transactions. This technique can help identify odd transactions within a group. By applying it to the risky group, the result of the clustering can highlight the most dissimilar transactions for auditors to examine.

Currently, we use another statistical method called a "t-test" to compare a single value with all other values to determine whether the single value is abnormal. A cluster analysis would allow us to look at more than one value at once.

²¹ Won Gyun No, Kyungha (Kari) Lee, Feiqi Huang, and Qiao Li, "Multidimensional Audit Data Selection (MADS): A Framework for Using Data Analytics in the Audit Data Selection Process," *Accounting Horizons* 33, no. 3 (2019): 127-140.

²² Won Gyun No, Kyungha (Kari) Lee, Feiqi Huang, and Qiao Li.

Survey Results Show Denver Is a Leader in Local Government Audit Analytics

Our survey of local government audit organizations asked questions about how they use analytics in their audit work. The survey included questions related to the analytics tools they use, the specific types of analyses they use, and the ways they report their results.

When we compared the results to our own practices, we learned:

- Organizations with dedicated analytics resources are associated with more advanced and more frequent use of analytics in audit work — which enables auditors to securely, quickly, and effectively examine their organizations' data both from individual transactions and from data used to manage overall processes.
- The tools used by Denver's Audit Analytics Team are both traditional and advanced when compared to other organizations that responded to the survey.
- Our analytics team uses many advanced analytics to find risky transactions.
- Our office reports our results in more ways than most organizations.
- Our peer organizations apply analytics in some novel ways — particularly using statistics to identify data-reliability issues, applying cluster analysis to find risk, and using tools to read text.
- Some organizations have automated how they report their results.

Audit Analytics Resources and Tools

A successful audit analytics program needs both knowledgeable staff and specialized tools capable of accessing, cleaning, analyzing, and reporting on a variety of data. Audit analytics skills and approaches are a growing necessity in both the public and private sectors.

Our survey of local government audit organizations in the U.S. and Canada found dedicated analytics resources are more common in larger audit organizations. For example, nearly 75% of the largest local government organizations (i.e., those with 26 or more auditors, like Denver's) that answered our survey have dedicated analytics resources. Only 5% of the organizations with 10 or fewer auditors have such resources.

While we do not know why this is, it is likely that larger audit organizations:

- Have more means to acquire or develop analytics resources.
- Are associated with larger municipalities that are more likely to be digitized and, therefore, to hire staff that are more digitally savvy.²³

Our office's Audit Analytics Team is among the largest dedicated teams reported in the survey. One other audit organization said it had a team of three dedicated analytics staff — while eight organizations reported having one full-time-equivalent staff member dedicated to analytics. Another reported having a staff member dedicated to analytics 25% of the time.

²³ Luiz de Mello and Teresa Ter-Minassian, "Digitalisation Challenges and Opportunities for Subnational Governments," OECD Working Papers on Fiscal Federalism, no. 31 (2020): 15, accessed Feb. 2, 2022, <https://doi.org/10.1787/9582594a-en>.

Two audit organizations said they were hiring a data scientist and building out an audit analytics program.

The immediate impact of having dedicated resources appears to be a stronger audit analytics program.

We found audit organizations with dedicated analytics resources are more likely to frequently use or have automated analytics for risk assessments and data-quality checks and to check whether controls — those safeguards like policies, procedures, or strategic plans meant to ensure a program or process operates as intended — are working as planned.

Even though our office has significant dedicated analytics resources, we have also built analytics skills among all our audit staff. Since 2017, we have regularly offered internal training on Microsoft Excel, Tableau, and Arbutus, an audit software program.

Even though our office has significant dedicated analytics resources, we have also built analytics skills among all our audit staff.

Research shows that providing training opportunities results in more use of audit analytics.²⁴

In 2021, the Denver Auditor’s Office began a focused effort to train our auditors on Python — a popular computer language for performing a wide range of functions such as connecting data sources, preparing data for analysis, and then analyzing and visualizing data. To build auditors’ skills in this language, we made external online courses available and encouraged our staff to use their new skills in their audit work or in working directly with our analytics team.

By encouraging all our auditors to use Python, we can now perform more sophisticated risk assessments and control tests during our audits. Furthermore, it gives our staff the skills they will need to continue being effective auditors as more organizations move toward digitally storing and processing information.

TOOLS FOR AUDIT ANALYTICS – There are many computer languages and software programs that auditors can use to analyze data or write scripts — commands that perform a series of tasks — to automate the analysis of data.

Python is a tool that makes more sophisticated audit analytics possible. However, our survey results found few organizations use computer languages — such as Python or others like SQL or R — to write scripts, when compared to using audit software such as Arbutus, Galvanize, or IDEA to perform analyses or to automate their analyses with scripts.

Manual operations in Excel are still the primary tool most local government auditors we surveyed use. Given most organizations’ general audit staff perform their analytics, rather than a dedicated analytics staff member doing it, their use of a well-known, widely available tool like Excel makes sense.

²⁴ Clark Hampton and Theophanis C. Stratopoulos, “Audit Data Analytics Use: An Exploratory Analysis” (2016), available via SSRN, accessed Feb. 22, 2022, <https://ssrn.com/abstract=2877358>, 18.

The Denver Auditor’s Office is leading the way in using Python to implement data science tools in local government auditing rather than pre-made audit software. This has several benefits:

- Python is one of the world’s most popular – and growing – computer languages. More online resources for Python exist than for other computer languages used in software like Arbutus, Galvanize, or IDEA.
- Python skills are relatively less expensive to develop and becoming more common. Python courses are readily available and inexpensive compared to training on pre-made audit software. High schools and universities are using languages like Python across multiple subjects, including math and biology.²⁵ As such, recent graduates will likely already have skills in Python or other common computer languages.
- Python and other computer languages, like R and SQL, are free to access. This makes it cheaper for local government audit organizations to have analytics programs than if they relied on subscription-based programs like Arbutus, Galvanize, and IDEA.

Figure 1 on the next page shows the many tools available for performing analytics and the number of audit organizations in our survey that said they use each tool and how they do so.

MANUAL ANALYSIS – Along with our more advanced tools, the Denver Auditor’s Office also uses Excel to manually analyze data, which is consistent with most of the audit organizations that answered our survey.

Given the prevalence of Excel files and the familiarity with Excel across nearly every government unit in the City and County of Denver, Excel continues to be a valuable tool for our audit staff to know how to use.

The audit organizations that answered our survey said they also used other software for manual analysis. The four most common after Excel included Galvanize, Power BI, Access, and IDEA.²⁶

Audit organizations that have dedicated analytics resources are more likely to use advanced analytics tools, thereby enhancing audit techniques.

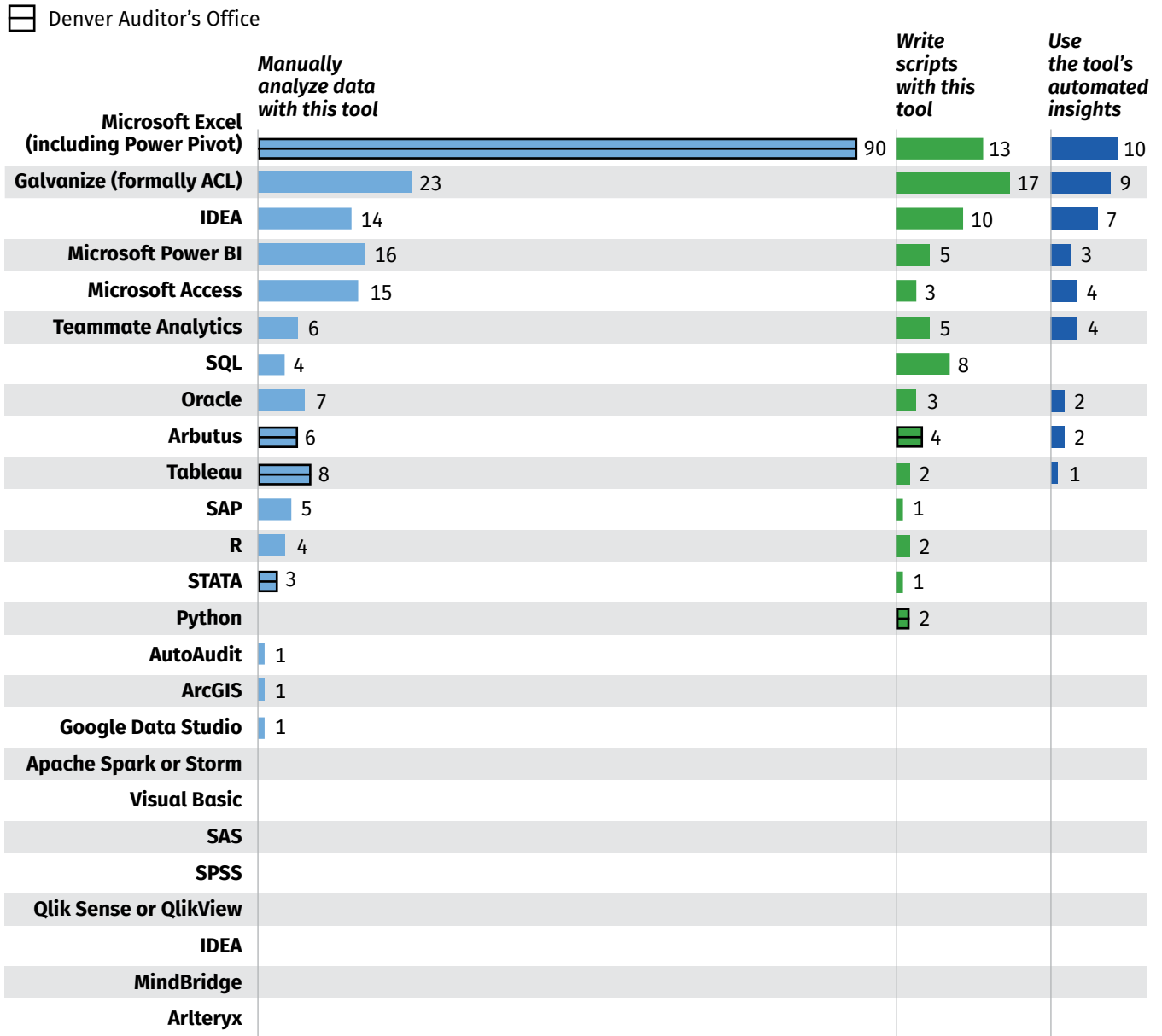
SOFTWARE USED TO WRITE AND RUN SCRIPTS – Audit organizations in our survey are more likely to use the scripting abilities of pre-made auditing software tools, like Galvanize or Arbutus, than they are to use computer languages like R, Python, or SQL to write scripts.

For example, only 12 audit organizations said they used R, Python, or SQL to write scripts, compared to 44 organizations that said they use pre-made software such as Arbutus, Galvanize, or IDEA to write scripts. Our office uses Arbutus and Python to connect to and clean data and to automate our analytics. They each have strengths and weaknesses, so we use them in a complementary fashion.

²⁵ Philip Guo, “Python Is Now the Most Popular Introductory Teaching Language at Top U.S. Universities,” Communications of the Association for Computing Machinery, July 2014, accessed Feb. 7, 2022, <https://cacm.acm.org/blogs/blog-cacm/176450-python-is-now-the-most-popular-introductory-teaching-language-at-top-us-universities/fulltext>; Jennifer Xu and Mark Frydenberg, “Python Programming in an IS Curriculum: Perceived Relevance and Outcomes,” Information Systems Education Journal 19, no. 4 (2021): 37-54, accessed Feb. 7, 2022, <https://files.eric.ed.gov/fulltext/EJ1310052.pdf>.

²⁶ Galvanize was previously called “ACL.”

FIGURE 1. Analytics Tools and the Ways Local Government Auditors Engage with Them



Note: Organizations could choose more than one tool and use of each tool.

Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

For some data connections, we prefer Arbutus because it has built-in data protection that prevents the person who looks at the data from changing the source data. This is important when connecting to and analyzing data on an active city system, like Denver's tax system. Arbutus also allows us to schedule regular updates of the data.

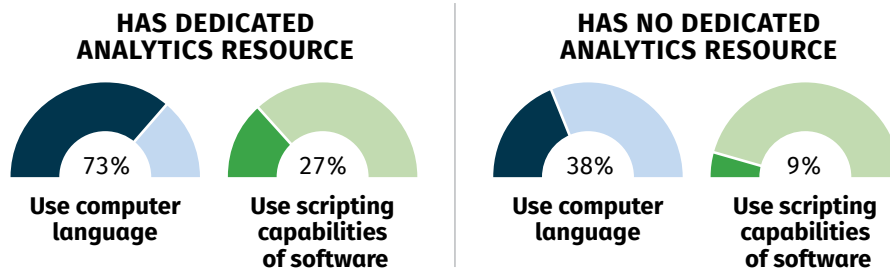
Other local government auditing organizations we surveyed said they use software such as Teammate Analytics, IDEA, Power BI, Access, Oracle, Arbutus, Galvanize, and even the language used to automate Microsoft

Excel to write their scripts.

Within our survey results, the audit organizations that have dedicated analytics resources are more likely to use these advanced analytics tools.

For example, as shown in Figure 2, 73% of audit organizations with dedicated analytics resources use audit software such as Arbutus, Galvanize, and IDEA to write scripts and 27% use languages like R, Python, or SQL. By contrast, among the audit organizations that do not have dedicated resources, only 38% use audit software to write scripts and only 9% use R, Python, or SQL.

FIGURE 2. Percentage of Local Government Audit Organizations with Dedicated Analytics Resources that Use Scripting Capabilities or Computer Languages



Source: Auditor’s Office survey of Association of Local Government Auditors member organizations.

AUTOMATED INSIGHTS – Several tools offer automated insights or pre-made analytics. Users can perform the pre-made analyses by selecting a data field and clicking a button. Applying this kind of tool may be a growing trend, based on the presentations our auditors have attended at professional conferences in recent years.

However, our office has not used pre-made automated analysis tools like this. In many cases, how a tool conducts an analysis is not well documented, so it is difficult for us to validate the work. As the quality and use of automated analytics technology grows, we can learn more about it and identify when its applications may be appropriate.

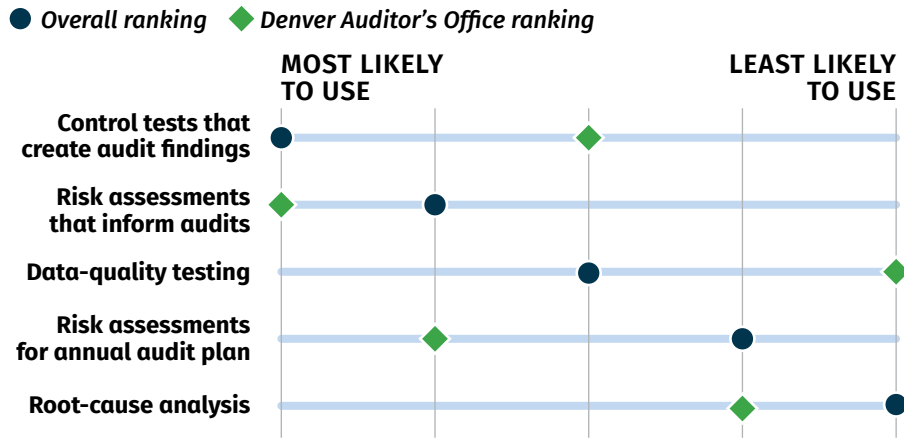
Analytics for Control Testing and Risk Assessment

Next, our survey asked local government audit organizations to rank how frequently they use analytics for five specific purposes.

As shown in Figure 3 on the next page: On average, they said they are most likely to use analytics to test controls (i.e., to verify whether a process is working as intended). The next most likely uses were for:

- Risk assessments for individual audits.
- Data-quality testing.
- Risk assessments for annual audit plans.
- Identifying the cause of an issue.

FIGURE 3. How Frequently Local Government Audit Organizations Apply Analytics for Selected Uses



Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

Our office's focus is different in that we use analytics most often for risk assessments for both audits and our annual Audit Plan. Our next most common applications of analytics are for control tests, identifying the causes of issues, and then assessing data quality. Our ranking may be different because of the analysis tools we use and because we have dedicated analytics staff.

The tools other audit organizations said they most commonly use (e.g., Excel, Arbutus, or Galvanize) are better for identifying specific conditions that could indicate a problem in a process, rather than using statistics to identify risk. The tools we employ most — Python and a statistics analysis software called STATA — are better for applying statistical analyses in addition to testing conditions.

Furthermore, the survey results show that those organizations that have dedicated analytics staff are more likely to use statistics-based analyses than organizations without dedicated staff.

FOR MORE INFORMATION
For additional details on our survey results, see [Appendix B](#).

Of note, data-quality testing was the third most-common application for analytics among the audit organizations we surveyed, but it was the lowest-ranked use of our analytics tools.

“Data quality” refers to how accurate information in a system is. While we do check for data quality, we use traditional auditing methods such as sampling and document review to do this. We learned from our survey results that some local government audit organizations are using statistics to identify potential issues with data.

Based on these results, analytics for data-quality testing is an area our Audit Analytics Team can learn more about — with plenty of

examples from other local government audit organizations to guide us. [Appendix B](#) discusses in more detail the specific types of analyses other local government audit organizations said they use.

Analytics Reporting and Responses

The way in which the Denver Auditor’s Office uses and reports our analytics results is similar to most audit organizations we surveyed. But we learned we lag in using newer technologies to automate notifications to audit staff about issues our analytics identify.

As such, this is an area for the Denver Auditor’s Office to consider. We could identify where these technologies would improve our internal efficiencies or the effectiveness of our audit analytics, while maintaining our standards to verify the results.

REPORTING RESULTS – The Denver Auditor’s Office communicates our analytics results in a variety of ways. For example:

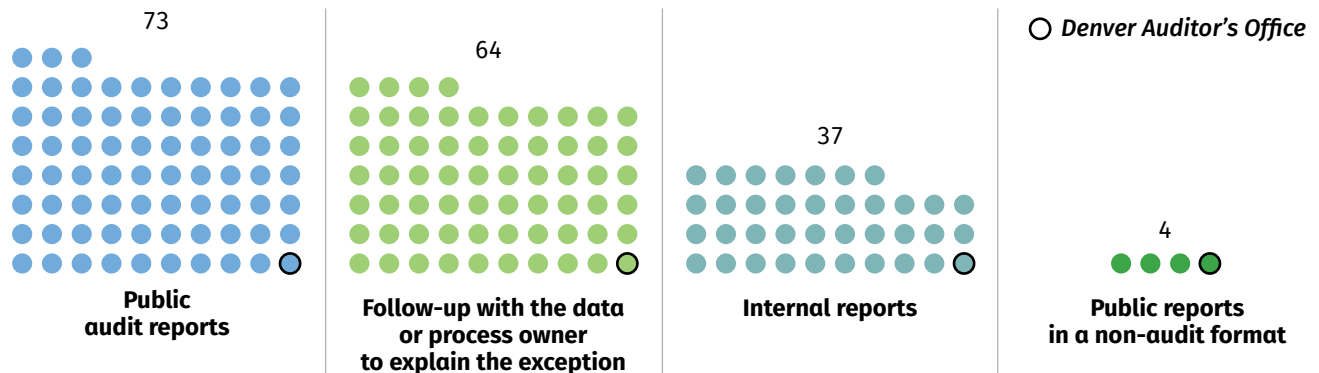
- We publish the results of our original audits and follow-up audits.
- We present summary results directly to city agencies at the end of each new continuous audit project or risk assessment.
- We report detailed results through work papers to the Auditor’s Office’s executive leadership to help with our risk assessment process.
- We report our analytics work to the public and the Independent Audit Committee twice a year as part of a semiannual update about the Audit Analytics Team’s efforts.

Some of these approaches are more popular than others among the local government audit organizations we surveyed.

For example, as shown in Figure 4, only three other organizations said they published their analytics results to the public in a non-audit format, like Denver does through our semiannual updates to the Audit Committee.

Our survey showed us we lag in using newer technologies to automate notifications to audit staff about issues our analytics identify.

FIGURE 4. How Local Government Audit Organizations Report Audit Analytics Results



Note: Organizations could select all applicable options.

Source: Auditor’s Office survey of Association of Local Government Auditors member organizations.

AUTOMATING HOW WE SHARE ANALYTICS RESULTS – Along with advances in analytics, the audit profession is adopting innovations that connect analytics results with communications tools and business processes. Two specific innovations include automated triggers and robotic process automation.

For example, if an analysis found a risky transaction, an “automated trigger” might either stop the transaction or send an alert about the transaction. “Robotic process automation” is a tool that mimics and automates a routine task on a computer, such as writing an email with an attachment and recording the response.

These two technologies are often combined. For example, a credit card company’s analysis to identify a potentially fraudulent transaction could trigger a hold on a transaction and then begin an automated process to notify the customer about the charge with a copy of the transaction — and then record whether the customer says the charge was authorized.

While our office does not use automated triggers or automatic reporting, we found some local government audit organizations have implemented these types of tools. Four organizations that responded to our survey said they have a follow-up process that their analytics trigger, and 20 said they have a trigger that intervenes in a business process or financial transaction.

While auditing standards across the public and private sectors vary, the generally accepted government auditing standards the Denver Auditor’s Office is required by city charter to follow help us maintain firm independence between our audit staff and city management.²⁷ To that end, we make only recommendations — we do not intervene in policies, operations, or management of the City and County of Denver’s processes.

Before our office were to use this kind of technology, we would need to consider how we would apply it and determine whether it would affect our audit independence.

For example, we typically communicate our results or follow up to gather more information about a risky transaction our analytics flag. We might consider using automated triggers and robotic process automation to improve the efficiency of how we share our continuous audit results while still not intervening in any management decision, like halting a business process.²⁸

²⁷ U.S. Government Accountability Office, GAO-21-368G, “Government Auditing Standards” (2021).

²⁸ Durmuş Acar, Graham Gal, Mahmut Sami Öztürk, and Hayrettin Usul, “A Case Study in the Implementation of a Continuous Monitoring System,” *Journal of Emerging Technologies in Accounting* 18, no. 1 (2021): 17-25.

APPENDICES

Appendix A – Methods for Surveying Other Audit Organizations and Reviewing Professional Literature

Literature Review Methods

To find relevant peer-reviewed research on audit analytics, we used the search terms “audit analytics” and “survey on audit analytics” within Google Scholar. Next, we found more articles using the references from the initial publications our Google search identified. We focused on articles published between 2019 through 2021 unless the material appeared especially relevant.

We used a similar approach to identify professional publications and relevant websites using Google’s regular search engine. In this search, we used the terms “audit analytics,” “survey on audit analytics,” “continuous audit,” and “fraud analytics.”

Survey Methods

To gather information from other local government audit organizations on their uses of audit analytics, we partnered with the Association of Local Government Auditors to obtain the association’s membership list. The list included 273 organizations and the email address for each organization’s primary contact.

We then created a survey using SurveyMonkey and emailed it to each organization in the fall of 2021. The survey included 12 questions asking each audit organization about:

- Its capacity for audit analytics.
- Where its auditors applied audit analytics for risk assessment, control tests, or data quality.
- The tools its auditors used for analytics.
- The datasets its auditors typically applied those analytics to.
- The follow-up procedures its auditors use when the analytics identified an issue.

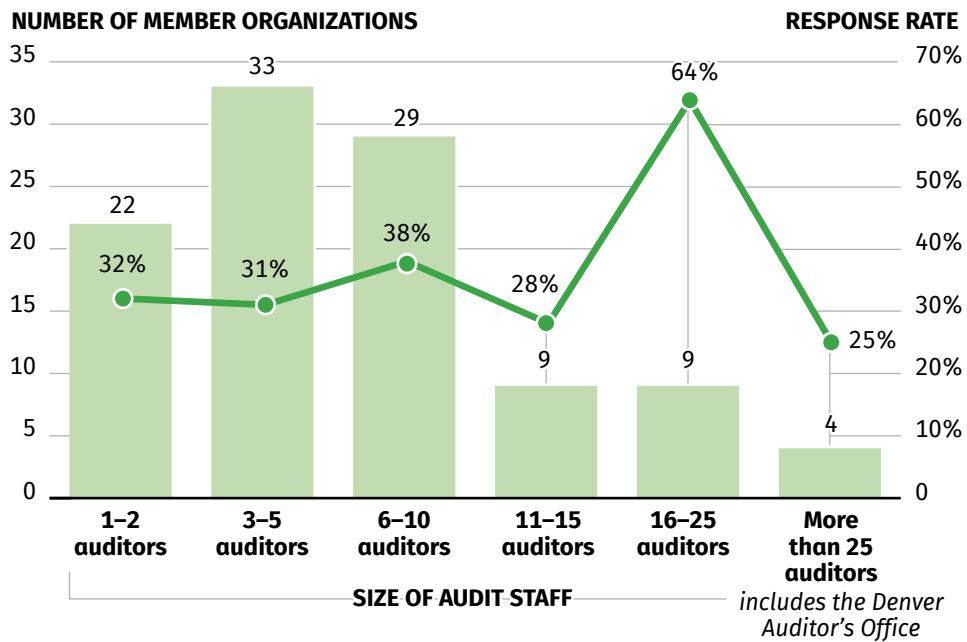
One hundred fifty-six recipients opened the email, 129 clicked the link to start the survey, and 107 responded either partially or fully. On average, the survey took seven minutes to complete.

The Association of Local Government Auditors categorizes the size of each local government audit organization based on the number of auditors on staff. To examine how representative our survey results were, we calculated our response rate from each of the association’s member-size categories. As shown in Figure 5 on the next page, we received responses from about 30% within each group except the two groups that make up the “extra-large” category: those organizations with 16-25 auditors and those with 26 or more auditors.²⁹

We received responses from two-thirds of the organizations with 16-25 auditors and only four responses, or 25%, from the largest organizations. Denver is among the largest size for local government audit organizations.

²⁹ Question 1 of the survey asked each audit organization to provide the number of auditors it had.

FIGURE 5. Survey Participation Rate of Association of Local Government Auditors Member Organizations, by Organization Size



Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

While we had a slightly below-average response from our peer group of audit organizations with 26 or more auditors, we did receive responses from those we consider most similar in size and application of analytics tools. As such, we believe our survey results include a good representation of how other local government audit organizations are using analytics to support the audit function.

Appendix B – Additional Survey Results

This section provides the remaining results from our survey of local government audit organizations, including the detailed questions we asked about the types of analytics each organization uses.

We also include a comparison of the types of analytics used between organizations with and without dedicated resources. Finally, we provide the results from the questions we asked about how the results of an organization's analytics are addressed.

Types of Analytics Local Government Audit Organizations Use

We asked the local government audit organizations we surveyed to identify how frequently they used analytics specifically for:

- Statistical analysis to identify control failures or for risk assessment.
- Statistical analysis for assessing data quality.
- Non-statistical assessments of controls and risk.

For each category, we listed a series of analytics that our team has applied, read about, or learned about from other analytics groups. We wanted to create a broad range of analyses that included methods beyond our current portfolio. The organizations we surveyed could identify whether they used a specific analysis and then how often they used each one. Beginning on the next page, figures 6, 7, and 8 illustrate the results, along with our own responses.

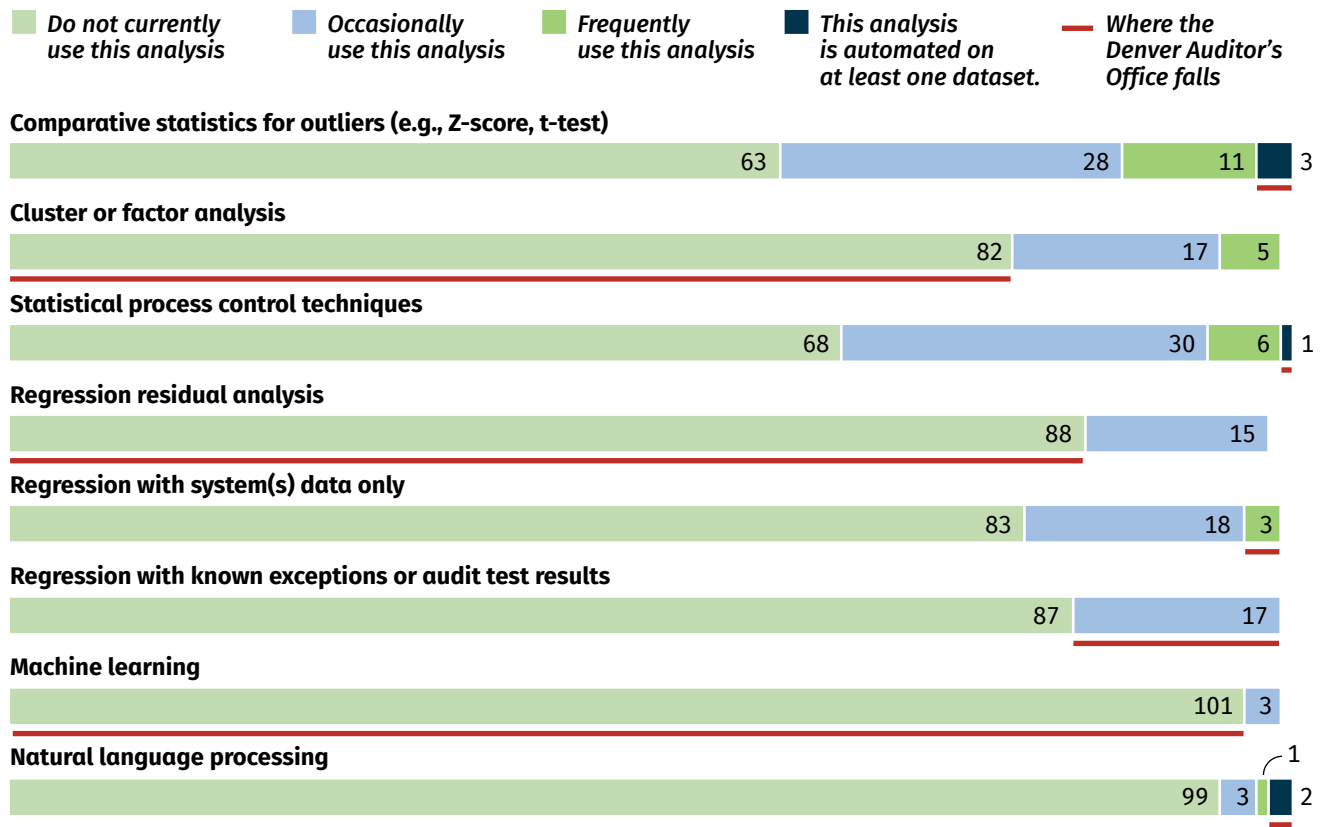
Beginning on [page 25](#), figures 9, 10, and 11 compare the results of how often audit organizations use each specific analytic between those shops with dedicated analytics resources and those without dedicated analytics resources. As we discussed, audit organizations with dedicated analytics resources are more likely to perform analytics frequently or to automate their analytics.

Then, on [page 28](#), figures 12 and 13 illustrate the extent to which audit organizations' analytics are integrated with other processes.

As Figure 12 shows, only four organizations that responded to our survey have automated a follow-up process triggered by one of their analytics. Similarly, Figure 13 shows 20 organizations said their analytics trigger or intervene in either a business process or financial transaction.

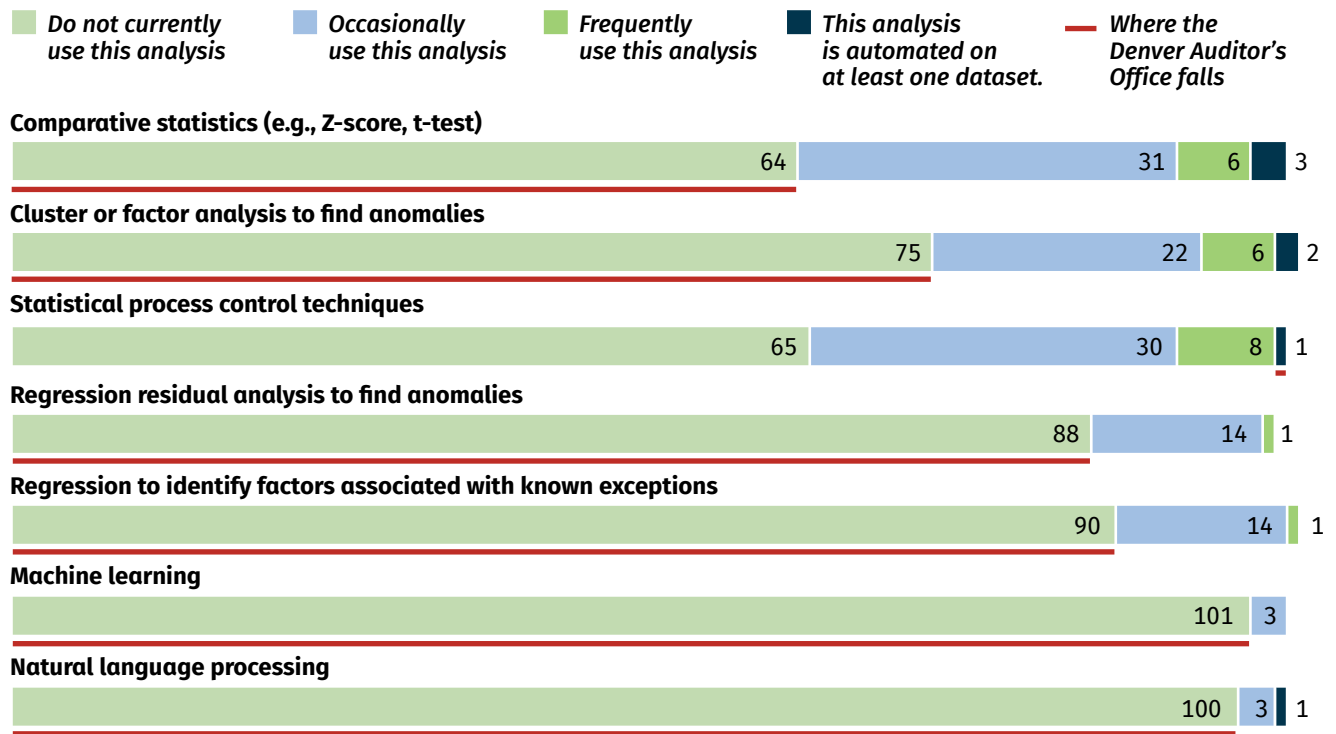
From these results, we learned that while technologies exist to automate responses based on the outputs of an analytic, few local government audit organizations have integrated those capabilities into their processes.

FIGURE 6. Number of Local Government Audit Organizations that Use Certain Types of Analytics to Identify Risk or Control Failures



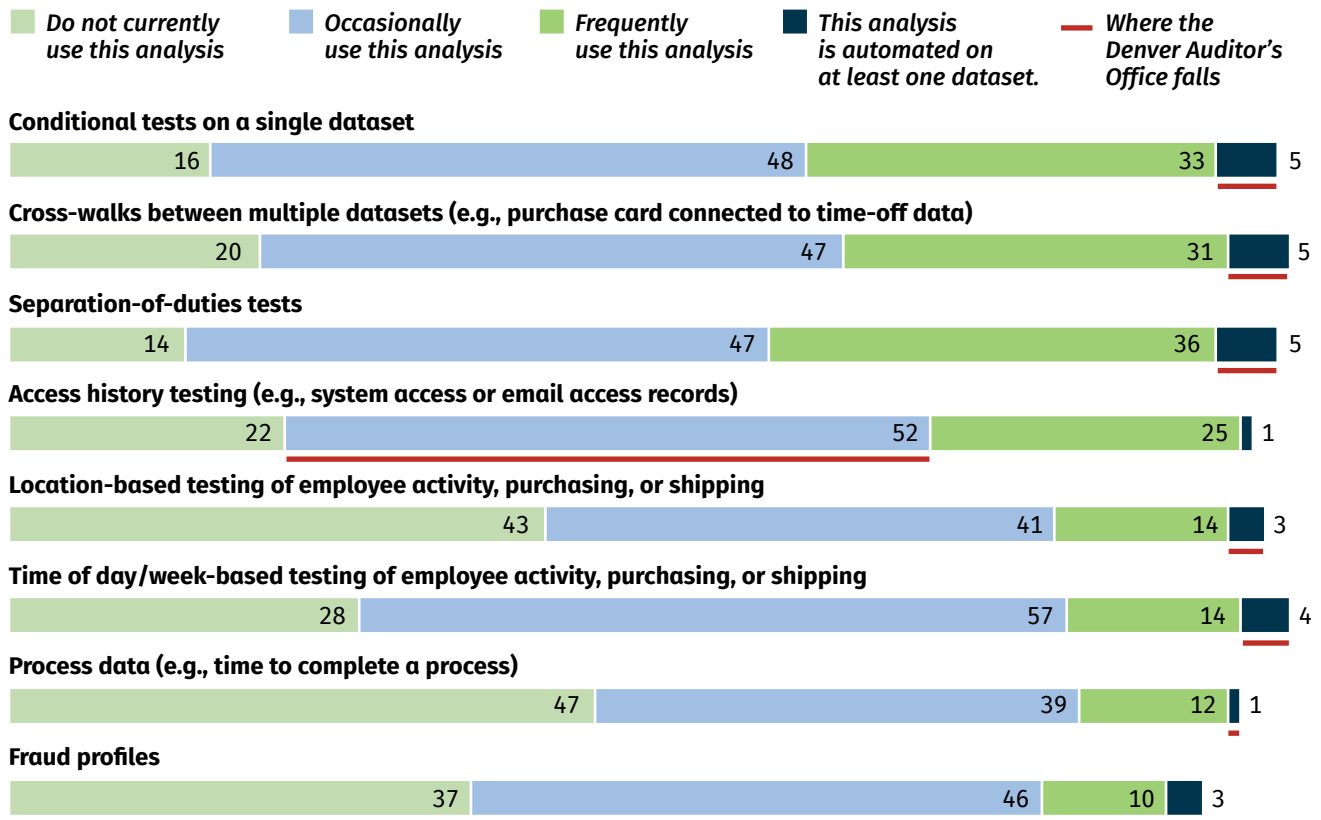
Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

FIGURE 7. Number of Local Government Audit Organizations that Use Certain Types of Analytics to Identify Data-Quality Issues



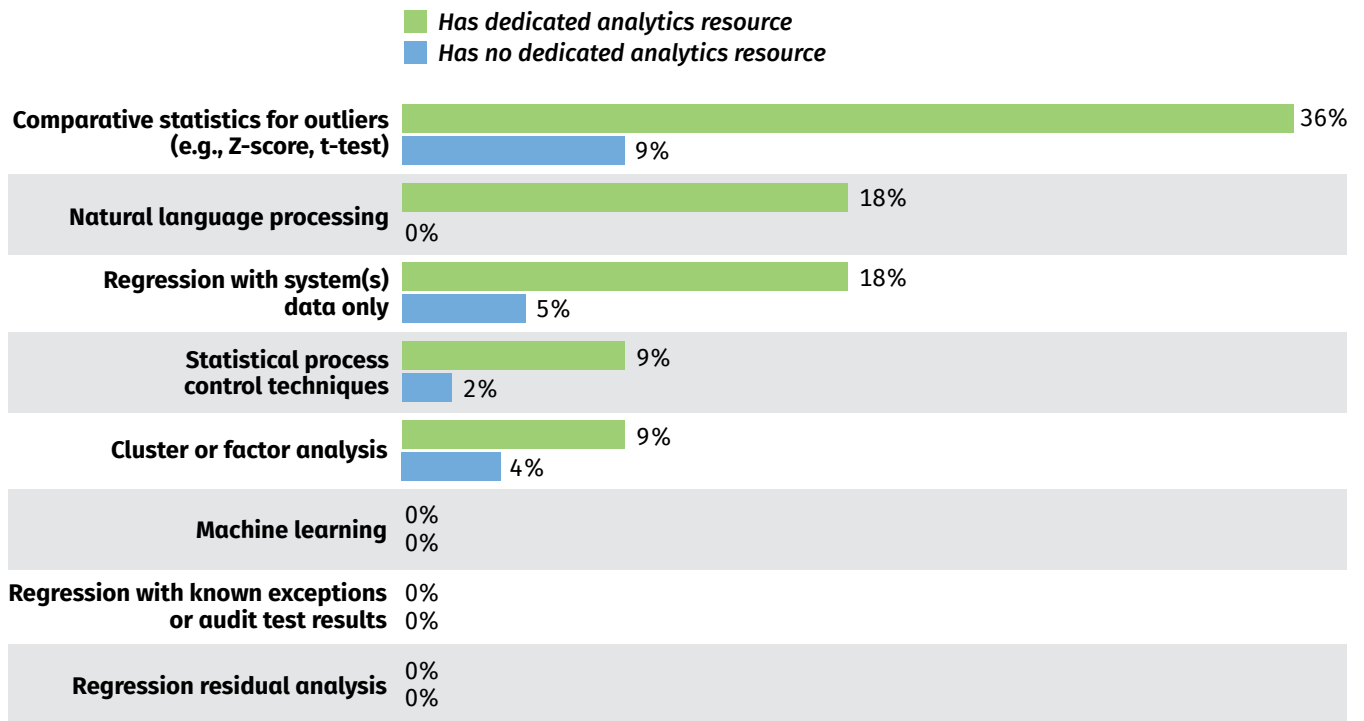
Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

FIGURE 8. Number of Local Government Audit Organizations that Use Non-Statistical Assessments to Identify Risk or Control Failures



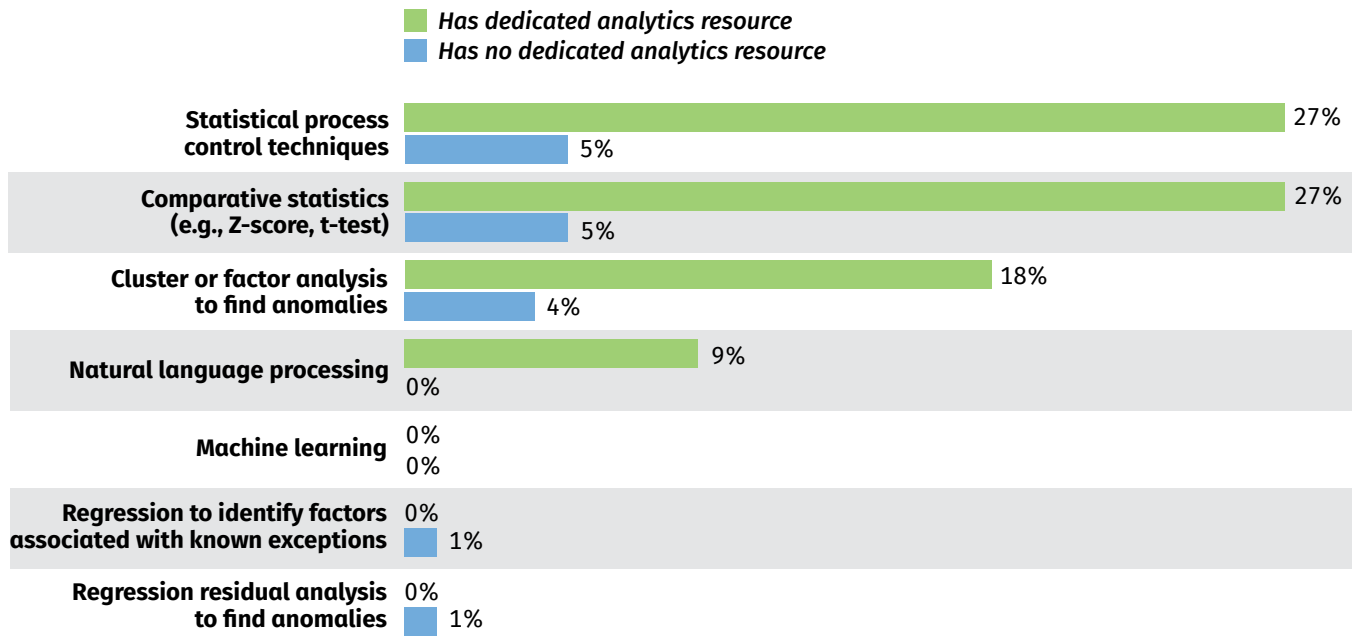
Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

FIGURE 9. Percentage of Local Government Audit Organizations that Are Frequently or Have Already Automated Their Analytics to Identify Risk or Control Failures



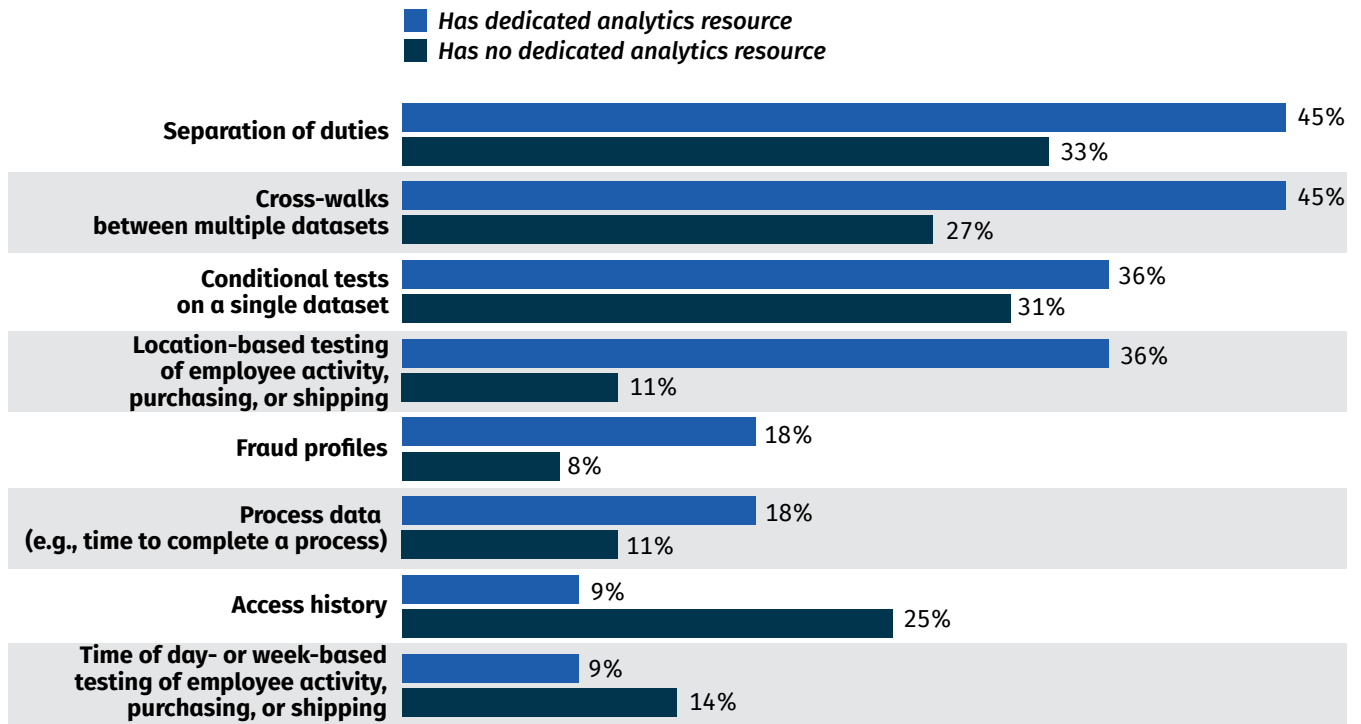
Source: Auditor’s Office survey of Association of Local Government Auditors member organizations..

FIGURE 10. Percentage of Local Government Audit Organizations that Are Frequently or Have Already Automated Their Analytics to Identify Data-Quality Issues



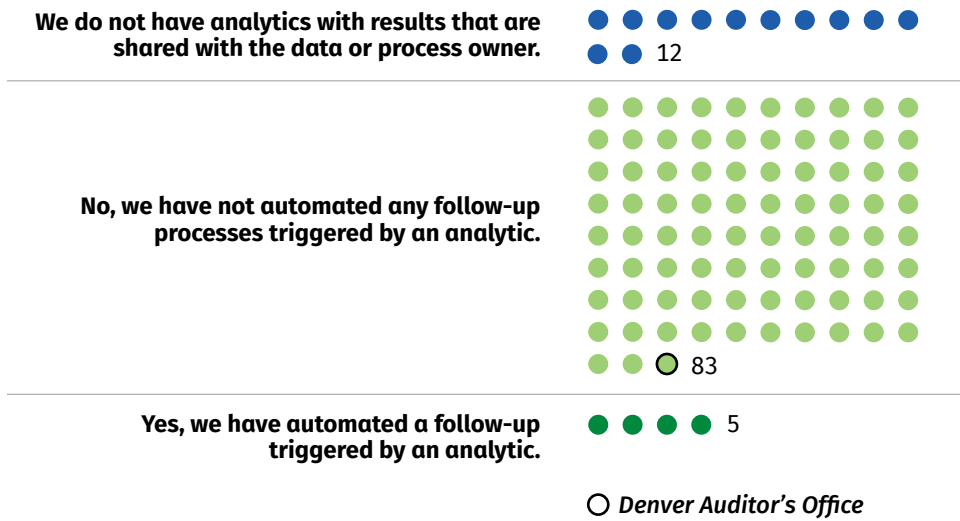
Source: Auditor’s Office survey of Association of Local Government Auditors member organizations.

FIGURE 11. Percentage of Local Government Audit Organizations that Are Frequently or Have Already Automated Their Non-Statistical Analytics to Identify Risk or Control Failures



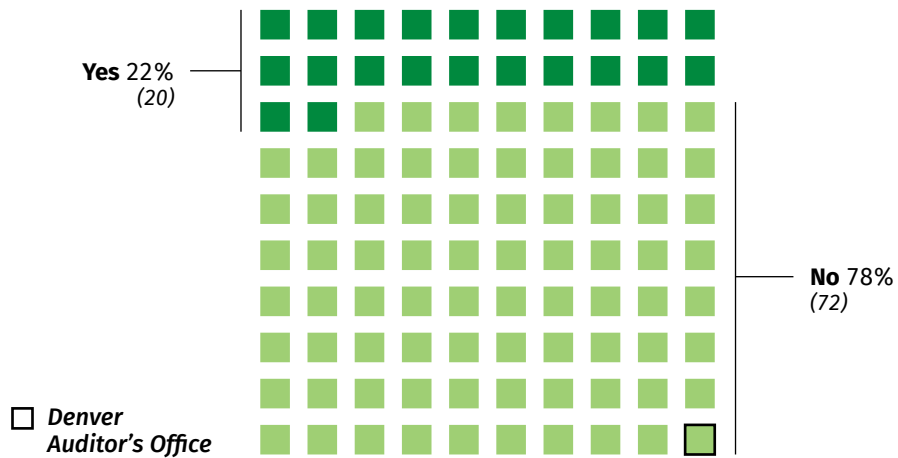
Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

FIGURE 12. Number of Local Government Audit Organizations that Follow up when Analytics Identify an Exception or that Have Automated Follow-up Processes to Gather More Information



Source: Auditor's Office survey of Association of Local Government Auditors member organizations.

FIGURE 13. Number of Local Government Audit Organizations with Analytics that Trigger or Cause an Intervention in a Business Process or Financial Transaction



Source: Auditor's Office survey of a sample of Association of Local Government Auditors member organizations.

Appendix C – Sources for Accounting Firms’ Discussions on Audit Analytics

- “Audit Data and Analytics,” KPMG, accessed Feb. 22, 2022, <https://home.kpmg/xx/en/home/services/audit/audit-data-analytics.html>.
- “Data and Analytics,” PwC, accessed Feb. 22, 2022, <https://www.pwc.com/gx/en/services/audit-assurance/risk-assurance/it-risk-assurance/data-and-analytics.html>.
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- Ken Tysiac, “How Firms Are Delivering Value with Audit Data Analytics,” Journal of Accountancy, Jan. 21, 2020, accessed Feb. 22, 2022, <https://www.journalofaccountancy.com/news/2020/jan/cpa-firm-value-audit-data-analytics-22751.html>.

Office of the Auditor

The **Auditor** of the City and County of Denver is independently elected by the residents 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 residents' confidence and avoiding any appearance of a conflict of interest.



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