NCHRP Synthesis 584 Visualization for Highway Performance Measures Summary

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ABSTRACT
NCHRP Synthesis 584 Visualization of Highway Performance Measures was published in July 2022 and was the most downloaded TRB document that month. The synthesis showed how states tell their performance story with visualizations that resonate with their audience.

This paper highlights five key takeaways:

1) **Keep it Simple.** Use maps, line, bar, and pie charts with a title that tells the story.
2) **Connect to the Audience.** Your message must be seen and remembered.
3) **Tell a clear story.** Visualizations communicate the story that will be shared.
4) **Make data transparent.** It builds trust.
5) **Leadership Matters.** Top-down support encourages bottom-up excellence.

The synthesis showcased five stories shared from the state interviews:

- Use performance journalism to tell their agency’s story – Washington State DOT
- Online dashboard makes an impact to improve on-time performance – Virginia DOT
- Multimodal Mobility Performance Measures help move Florida – Florida DOT
- Online dashboard tells the Utah Performance Story – Utah DOT
- Follow the Leader to Lead by Example – Arkansas DOT

The complete report ([https://nap.nationalacademies.org/catalog/26651/visualization-of-highway-performance-measures](https://nap.nationalacademies.org/catalog/26651/visualization-of-highway-performance-measures)) includes an appendix with the answers to the survey questions. Metro Analytics developed a dashboard as part of an externship program with Rutgers University to visually display the survey answers. The current website is: [https://public.tableau.com/app/profile/snehal.ajakkala/viz/NCHRPSynthesisDashboard_MetroAnalytics/VizTypeHexmap](https://public.tableau.com/app/profile/snehal.ajakkala/viz/NCHRPSynthesisDashboard_MetroAnalytics/VizTypeHexmap)

Keywords: Visualization, Performance Measures, Dashboard, Infographics, Maps
FIGURE 1 Visual, Audience, and Story are three key communication elements. (NCHRP Synthesis 584 Figure 35. Telling the performance story with visualizations that resonate with the intended audiences)

NCHRP Synthesis 584 Visualization of Highway Performance Measures¹ was published in July 2022 and was the most downloaded TRB document that month. The synthesis showed how states tell their performance story with visualizations that resonate with their audience, as shown in Figure 1.

The objective of this synthesis is to document the current practices and methods used by state departments of transportation (DOTs) for visualizing highway performance measures and their use of visualization techniques for communication and decision support. This synthesis focused on how visualization supports Transportation Performance Management (TPM), a strategic approach that uses performance data to inform decision making and outcomes. 44 states responded to a survey and one-on-one interviews with practitioners in five DOTs (WA, VA, FL, UT, AR) discussed their approach to visualizing performance measures.

The report showcased how telling meaningful data-based performance stories is more than just reporting data.

- **Effectively communicate** a clear story that brings data to life for its intended audience.
- **Dashboards** can tell a story that enables collaboration.
- **A few dedicated people** can transform data into performance stories.

This synthesis showcases hundreds of examples from around the country. Some key success factors include:

- **Keep it simple.** Use line, bar, and pie charts with a title that tells the story.
- **Make data transparent.** Accurate, consistent information builds trust over time.
- **Connect to the audience.** Deliver information they can use.
- **Tell a clear story.** Visualizations reinforce the story that will be remembered.
Although the synthesis reports on highway performance measures, the lessons learned can be applied to any visualization used to tell a story. The results are summarized in five takeaways and how five states used visualization to tell their performance story. The entire report is available at: nap.nationalacademies.org/catalog/26651/visualization-of-highway-performance-measures.

The five takeaways are drawn from the author’s reflection on the Summary of Findings reporting key success factors identified by the state DOTs that responded to the synthesis survey and participated in the follow-up interviews. The state stories provided the author a deeper insight into how the states approached visualization, the successes they observed and the challenges they faced. The five state stories do not directly apply the five takeaways. This paper summarizes the findings of the synthesis and succinctly describes the stories told by the state DOTs.
FIVE TAKEAWAYS

TAKEAWAY 1: Keep it Simple.
Use maps, line, bar, and pie charts with a title that tells the story.

![Bar Chart](image)

FIGURE 2 This bar chart demonstrates how a title, subtitle, and graphic simply communicate the story that farm products continue to make up the largest share of freight shipped by rail. (NCHRP Synthesis 584 Figure 38 Infographic Examples)

Simplicity in the design of the visualizations is a key success factor. “Keep it simple” was repeated by all the states interviewed. Success was often reported when a simple visualization effectively communicated a clear story that brought the significance of the raw data to life for its intended audience.

Figure 2 shows how using a clear title and subtitle that ‘tells the story’ shown by the graphic is an effective way to ‘keep it simple.’ Graphics can visually communicate data in an effective way that is quickly processed by our brains. The words that describe the graphic help a user understand what is important. The example in Figure 2 reinforces the data that farm products make up the largest share of freight, more than twice as much as hazardous materials. The proportion of freight is easily determined by looking at the graph. The graphic also shows that more goods were shipped in 2018 than in 2017, even though that information is not included in the story.

However, achieving simplicity is hard. Achieving simplicity requires considering many factors, such as:
- the text that describes the data story
- the clarity of the message
- effectiveness of the visualization

Bottom Line: Simply tell a performance story with visualizations that resonate with your audience.
TAKEAWAY 2: Connect to the Audience.

Your message must be seen and remembered.

FIGURE 3 This dashboard from Iowa was popular with the general public. It displays the location of the snow plows and a dash cam showing the current conditions. (NCHRP Synthesis 584 Figure 34 Performance highlight from Iowa)

State DOTs dashboards deliver information in a structured system that communicates with multiple levels of clearly defined audiences. Sharing the same data, information, and stories with internal and external partners helps them work together to accomplish common goals.

The story and visualization should resonate with the intended audience:

- **Internal analysts** want detailed data to find problems and solutions.
- **Internal decision-makers** have to prioritize and manage limited funding.
- **External stakeholders** make decisions and provide funding.
- **External audiences** want to know how well the system is functioning.

Visualizations like the dashboard shown in Figure 3 can create a foundation to build partnerships within DOTs and between interested stakeholders that enable collaboration. The challenge State DOTs acknowledge is that increasing amounts of data make it difficult to deliver performance measures effectively to all intended audiences.

Bottom line: A story-rich dashboard that supports the executive leadership’s message can help focus the organization’s work to meet its stated objectives.
TAKEAWAY 3: Tell a clear story.
Visualizations communicate the story that will be shared.

FIGURE 4 This graphic from the FDOT Sourcebook uses a simple line chart to show that VMT grows faster than population and licensed drivers. (NCHRP 584 Appendix C pg 26)

State DOTs are finding ways to tell their performance stories with effective visualizations that resonate with their audience. Data stories can:
- Document current status
- Show trend over time
- Show progress toward a target
- Support a policy
- Inform long-term planning
- Inform medium-term planning
- Inform day-to-day operations

However, telling meaningful data-based performance stories is more than just reporting data.
- A story is not effective if it is not seen or remembered.
- Even good stories (seat belts save lives) do not inspire action.

Figure 4 shows how to use text and data to show that the Daily Vehicle Miles Traveled in Florida are increasing even faster than the population, which is important for transportation planners to know.
FIGURE 5 Dashboards can effectively tell the performance story. This generic structure shows an approach to creating effective dashboards. (NCHRP Synthesis 584 Figure 45)

Of all the visualization examples reported, dashboards appeared to be a very effective tool for communicating the performance story. Thirty-five states (80%) reported the use of a dashboard by internal DOT analysts, and twenty-four states (55%) use a dashboard to share data with an external audience. Of the states interviewed, Figure 5 shows a generic approach that helps users understand the context of the data. An introduction shows a picture of the “forest.” Users can drill deeper into the data to explore individual “trees” and, where applicable, look at the detailed information for the “leaves.” One powerful aspect is that some dashboards can enable users to select the level of detail or view the performance data for a specific map area.
TAKEAWAY 4: Make data transparent.

Reporting data consistently over time builds trust.

FIGURE 6 This graphic demonstrates transparency and communicates the current status, even when it tells a negative story (more bridges require repair). (NCHRP Synthesis 584 Figure 42. Source: WSDOT)

A strong foundation of performance measure data is necessary to allow analysts to analyze and share information accurately and effectively as shown in Figure 6. An information-rich dashboard is an educational tool that allows more person-to-person time to focus on explanation, analysis, and solution strategy planning instead of locating data and finding reports. Story-rich dashboards can:

- Support the executive leadership’s message
- Transform the organization’s work as a whole
- Help meet stated objectives
- Drive desire for information and participation.

However, performance measure data has to be well-governed. DOTs have to adapt to become more resilient and responsive to the increased transparency that accurate performance measure reporting can create.

- The performance story told by the data is not always positive.
- Increased trust also creates the challenge of increased accountability.
- A lack of strong data governance makes using and sharing data difficult.
- Data gathering, maintaining, linking, and using data is a significant challenge.
- It is challenging to deliver all performance measures effectively to all intended audiences.

Much of the work currently being done at state DOTs in visualization is being accomplished by a talented and dedicated few. Visualization tools are becoming more sophisticated, easier to use,
and more powerful. The challenge is in establishing data governance. Executive leadership’s support and engagement is critical to:

- providing the internal cultural shift to transparently visualizing data
- Clearly communicating the data to external audiences

**TAKEAWAY 5: Leadership Matters.**
Top-down support encourages bottom-up excellence.

*FIGURE 7 These six steps show how to communicate performance. (NCHRP Synthesis 584 Figure 8)*

**Building partnerships within DOTs and between interested stakeholders enables collaboration.** Figure 7 shows a process for telling meaningful data-based performance stories that requires more collaboration than just reporting data.

- Dashboards help address a broad spectrum of challenges to mobility.
- Stakeholders can spend more time solving problems instead of finding data.
- Everyone is looking at the same data, delivered consistently over time.
- Progress takes time, and transparent data builds trust.

However, engaging executive leadership in shaping the DOT stories that incorporate performance accurately and telling the performance story is a considerable challenge. These individuals always have a significant demand for their time and the resources they manage. Delivering the performance story quickly in a clear visualization can improve the organization’s decision-making.
Visualization provides insights but does not yet offer a complete solution.

With so much data, delivering in an intuitive system is hard.

Even clear stories (seat belts save lives) are not enough for everyone to take action.

Determining ways to evaluate the effectiveness of visualizations would help.

Bottom Line: Encourage executive leadership support and engagement. It can be rewarded with bottom-up excellence that creates stronger leadership support.

Why it matters: It is no longer a matter of if visualization is used; rather, it is a question of how to use it most effectively to tell a performance story. From the examples shared in Synthesis 584:

- 80% of the visualization examples were simple charts with descriptions.
- Infographics help emphasize important points.
- Maps provide a rich context to understand where challenges exist.
- Dashboards maximize increasingly limited face-to-face meeting time.
- Finding solutions to challenging problems involves more complex visualizations.

STATE STORIES

Five states were interviewed to understand how they use visualizations to communicate performance measures. Washington State DOT pioneered performance journalism to tell the agency story because they believed in the power and value of this information to improve the overall performance of the state transportation system. Virginia’s dashboard was the key tool for change by publishing a dashboard that identified the current progress of planning and construction projects. Project on-time delivery improved dramatically after the dashboard was published. The most significant Visualization of Highway Performance Measures innovation of Florida DOT’s efforts has been their vision of visualizing data both horizontally (showcasing multimodal mobility performance measures) and vertically (ranging from local to state level). The Utah dashboard serves as UDOT’s “face” to decision makers and other transportation system stakeholders. When questions are asked, not only regarding performance measure data but also about UDOT, they can easily be answered by a referral to the Strategic Direction website. Arkansas DOT followed the lead of other state DOTs; it has already created several visualizations and is working toward creating its centralized performance management dashboard similar to those presented in the other case examples. The following summaries share the impact of their visualization, how they approach the process, and their target audience(s).
FIGURE 8 The Gray Notebook produced by WSDOT utilizes infographics and consistently communicates performance measures every quarter. (NCHRP Synthesis 584 Figure 36)

Use Performance Journalism to tell their agency’s story – Washington State DOT

Performance Journalism originated as a commitment to the people of Washington State to restore transparency, accountability, and credibility in WSDOT’s ability to meet performance expectations.

Approach
Visualizations use simple language. WSDOT verifies that the data is accurate and that information is visualized through charts, graphs, and infographics to inform their audience as shown in Figure 8. Performance Journalism communicates distinct stories. They explain the who, what, when, and where of what is most currently happening in the transportation system.

- Visualizations are designed for the general public.
- They transparently tell the stories based on facts.

Audience
The purpose is to inform decisions regarding where to allocate resources best and what efforts would be most effective. These audiences were defined as:

- the general public
- elected officials
- other stakeholders in the transportation community.
FIGURE 9 The Washington Multimodal Mobility Dashboard begins with eight measures and drills down to both corridor and spot data. (NCHRP 584 Figure 46)

Over 80 Gray Notebooks reporting performance measures have been published quarterly, and a new Multimodal Mobility Dashboard (see Figure 9) provides increasing levels of detail to inform the reader as they discover the performance story about the transportation system of Washington State.
FIGURE 10 The Dashboard developed by Virginia DOT uses visualization of performance to improve on-time project performance from 20% to 89%. (NCHRP 584 Figure 50)

Dashboard Makes an Impact – Virginia DOT

Virginia DOT has successfully used dashboards to communicate performance measures in construction projects, safety, and road conditions. Twenty years ago, only 20% of projects were completed on time. After creating a dashboard, Figure 10 shows that on-time performance has increased to 89%.

Approach

VDOT staff successfully created visualization tools for performance measures that identified real-world problems. Building on their experience led to further innovation of visualization that assisted in solving them. Green, yellow, and red colored dashboard dials effectively communicate the performance status of projects. Figure 11 shows how the Performance Measure Dashboard presents an overview of data that the user can explore to find more specific details.

Audience

The targeted audience is always the general public; the primary goal is simplicity. If a visualization is designed to communicate data simply enough to be understood by the general public, then it is an effective information tool for anyone who may need to use it.

- The SMART SCALE dashboard improved the management of both time and budget.
- It built trust by providing transparency with real-time data.
- It guides the selection of projects, people, and locations.
FIGURE 11 The Virginia Performance Measure Dashboard showcases seven performance measures and then drills deeper into each measure to provide project-specific data. (NCHRP 584 Figure 51)
FIGURE 12 Florida’s Source Book defines multimodal mobility performance measures for both people and goods. The new dashboard provides statewide and local data to improve stakeholder involvement. (NCHRP 584 Figure 54)

**Multimodal Mobility Performance Measures help move Florida – Florida DOT**

Florida DOT built partnerships within the transportation system using the digital FDOT Source Book. These visualization tools are currently being used to increase safety and efficiency in all modes of mobility for auto, bike, pedestrian, transit, aviation, and marine. It visualizes data for both people and goods movement.

**Approach**

Figure 12 shows The FDOT Source Book that was created to respond to customers' requests for data availability in a readily accessible and usable form. It provides visualization of multimodal data in an easy-to-understand visualized format with navigable categories such as:

- mobility, factors affecting mobility
- infrastructure
- safety
- accountability.

This resource allows previously inaccessible data to be used to increase efficiency, safety, and resource allocation horizontally across multiple modes and vertically, from the local to the state level.

**Audience**

Planners are their priority, with significant consideration of the data needs of the larger transportation community, followed by the general public.

- Partnerships allow for consideration of specific audiences on local levels.
- Customers requested complete and accurate data.
- The Source Book has created increased demand from an ever-wider audience.
Tell the Utah Performance Story – Utah DOT

Utah DOT staff transformed the Strategic Direction Report into a dynamic “living document” through a top-down and bottom-up collaboration. With support from leadership and strong data management, the Strategic Direction website (Figure 13) emphasizes the mission of UDOT in a logical, general-to-specific way.

Approach
Visualizations included in the Strategic Direction website present relevant data in a form that clearly and simply communicates the most significant point, or performance story, in the most effective direct manner possible.

- Start with the mission, vision, values, and strategic goals (infographic format).
- Tactical Measures and Metrics provide 16 specific performance measures.
- Nested dashboards require an analyst login to access.
- Regional dashboards provide consistent, detailed data.

Audience
The Governor’s Office and the legislature are the primary audiences, and the general public (as investors in the system) and internal users are ancillary. The dashboard allows person-to-person time to be focused on explanation, analysis, and solution strategy planning.
FIGURE 14 The dashboard guides users from the big picture of three core measures to sixteen specific measures and four regional dashboards with highly detailed information. (NCHRP 584 Figure 57)

UDOT has created a dynamic site (Figure 14) that:

- represents goals, work, and needs accurately and transparently,
- is easy-to-navigate and easy-to-understand, and
- makes it easier to identify and solve problems.

It is a communication tool that supports the decision-making community in making the system safer and more efficient overall.
FIGURE 15 Modeling on the success of other states, this dashboard was developed by a small team to show the condition of all bridges in Arkansas. (NCHRP 584 Figure 64)

Follow the Leader to Lead by Example – Arkansas DOT

Approach
With strong support and direction from leadership, a small staff has produced an impressive dashboard focusing on traffic safety and bridge maintenance. The Crash Analytics Dashboard project aims to ultimately show the location and severity of every crash throughout Arkansas, and the Bridge Data Dashboard (Figure 15) has both internally and externally facing tools.

- The Crash Analytics Dashboard can be filtered and visualized from the general to the increasingly specific.
- The Bridge Data Dashboard has made it exponentially faster to identify where and when specific bridges need to be replaced.

Audience
The primary audience is the decision-makers, to inform them about the department's current performance and to communicate any gap between current performance and targets. Secondly, sharing the dashboard with the public improves the DOT's transparency and accountability for how they spend taxpayers’ money. However, designing visualization tools for the public versus internal use is challenging.

- Internal tools display complex data and visualizations.
- Public tools reflect increased attention to clarity and simplicity.

Arkansas DOT modeled its approach on the success of other states. The tools are increasingly being relied on by stakeholders, so they are proceeding to create accurate, transparent, and consistently maintained tools.
Metro Analytics worked with an externship team at Rutgers University to create a Tableau dashboard that visualizes the information gathered by a survey completed by 44 states that informed the NCHRP Synthesis 584 Report Visualization of Highway Performance Measures. This dashboard (Figure 16) allows anyone to visually explore the data gathered by the synthesis and can be accessed here:

https://public.tableau.com/app/profile/snehal.ajakkala/viz/NCHRPSynthesisDashboard_MetroAnalytics/VizTypeHexmap

FIGURE 16 This dashboard is being developed to display the states' responses to the synthesis survey visually. It provides insight into comparing how different states approach visualization.
FIGURE 17 This single graphic provides a simple view of three critical performance measures, a high-level view of how the transportation system is functioning. The boxes highlighted in blue show how this data is being used to inform decisions. (NCHRP 584 Appendix C pg. 173)

CONCLUSIONS
The Synthesis reports how states tell their performance story with visualizations that resonate with their audience.

Five key takeaways are:
1) **Keep it Simple.** Use maps, line, bar, and pie charts with a title that tells the story.
2) **Connect to the Audience.** Your message must be seen and remembered.
3) **Tell a clear story.** Visualizations communicate the story that will be shared.
4) **Make data transparent.** It builds trust.
5) **Leadership Matters.** Top-down support encourages bottom-up excellence.

The interviews of five states showcased the impact that visualization can make by applying the principles identified in the synthesis. Washington State improved support and funding from the legislature using Performance Journalism. Virginia improved project on-time performance from 20% to 89% using a dashboard. Florida is engaging stakeholders by communicating mobility performance measures. Utah has developed a dynamic new dashboard (Figure 17) providing performance measures to enable stakeholders to collaborate more effectively. Arkansas was able to apply the lessons learned by other states to create an impressive dashboard to improve safety and bridge repair.

Following the publication of the report, a new dashboard visually shares the data results. The current version can be accessed here: https://public.tableau.com/app/profile/snehal.ajakkala/viz/NCHRPSynthesisDashboard_MetroAnalytics/VizTypeHexmap
REFERENCES

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3. Figure 2 NCHRP Synthesis 584 Figure 38.
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5. Figure 4 NCHRP 584 Appendix C pg 26.
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7. Figure 6 NCHRP Synthesis 584 Figure 8.
8. Figure 7 NCHRP Synthesis 584 Figure 36.
9. Figure 8 NCHRP Synthesis 584 Figure 46.
10. Figure 10 NCHRP Synthesis 584 Figure 50.
11. Figure 11 NCHRP Synthesis 584 Figure 51.
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14. Figure 14 NCHRP Synthesis 584 Figure 57.
15. Figure 15 NCHRP Synthesis 584 Figure 64.
16. Figure 17 NCHRP Synthesis 584 Appendix C pg. 173.