

NCHRP Project 03-128

Business Intelligence Techniques for Transportation Agency Decision Making
IMPLEMENTATION PLAN AND RESEARCH RECOMMENDATIONS

Prepared for
National Cooperative Highway Research Program
Transportation Research Board
of
The National Academies of Science, Engineering, and Medicine

Vaishali Shah
Ben Pecheux
AEM Corporation
Herndon, Virginia

Pat Noyes
Pat Noyes & Associates
Boulder, Colorado
December 2019

The National Cooperative Highway Research Program (NCHRP) is sponsored by the individual state departments of transportation of the American Association of State Highway and Transportation Officials. NCHRP is administered by the Transportation Research Board (TRB), part of the National Academies of Sciences, Engineering, and Medicine, under a cooperative agreement with the Federal Highway Administration (FHWA). Any opinions and conclusions expressed or implied in resulting research products are those of the individuals and organizations who performed the research and are not necessarily those of TRB; the National Academies of Sciences, Engineering, and Medicine; the FHWA; or NCHRP sponsors.

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1. INTRODUCTION

The common mission of departments of transportation (DOT) whether at the State, metropolitan, or local levels is to provide an efficient and safe transportation system that enhances economic prosperity and preserves quality of life. For agencies to fulfill their missions, individuals at every level must make decisions that contribute to agency goals and priorities. Data, when relevant, timely, reliable and delivered in an actionable format, has tremendous power to improve all levels of agency decision-making, enabling culture of high-performing, customer-centric stewards of transportation infrastructure and services. This is the potential of business intelligence systems.

Business intelligence (BI) is a way to improve upon what is being done now and to create opportunities for new efforts that help your agency better deliver on its mission. BI can be viewed from the lens of transforming manual and paper-heavy processes to automated process, as improvements through new information, and as a means for restructuring and simplifying decisions. Most transportation agencies use some level of BI for their various management systems (e.g., highway performance, pavement, bridge inventory, maintenance, safety, construction, financial, and resources). Agencies frequently use BI for federal and agency reporting requirements, automated monitoring (threshold alerts), dashboards, scorecards, and ad hoc queries. And in large part, the most immediate value that may be derived from BI is in the realm that transforms manual, paper-based processes to electronic and mobile device-based processes such as electronic bidding and contract award, digital plans and project reviews.

The purpose of this implementation plan is to recommend actions that apply the products of NCHRP 03-128 to move organizations to action and put the research into practice. Higher level BI (used in an integrated manner to directly support strategic decision making with information drawn from across the agency) is still in early stages and part of the evolving process with respect to culture and management in transportation agencies. This plan includes an overview of the research results, an implementation strategy, and measures of success.

2. RESEARCH RESULTS

The research activities of NCHRP 03-128 developed guidance on:

- BI adoption pathways
- Leadership, governance, and change for successful BI application
- BI tools and techniques
- Data management

Each of these is summarized in this section.

2.1. BI adoption pathways

NCHRP 03-128 looked at common approaches to BI adoption and found that it occurred as a bottom up or top down process in most organizations. The bottom up approach usually starts with a decision-making void or a pain point within the organization. BI champions look for BI techniques to remedy the pain point, setting up an environment in which an application can evolve, testing tools and processes and bringing in new data. As the effort grows, the champion will often publicize successes and identify

new areas for application for BI in the organization. Over time and in response to resistance and challenges, these pilot projects improve and begin to expand organically to new use cases.

In a top down pathway, leadership understands the changing role of data and information technology, and creates a dedicated environment to seed, measure, control, and grow new BI projects. Building on pilot projects, there is a migration to an organization wide data and BI environment with governance and policies adapted to a more distributed format with increased responsibilities in each business unit. Leadership fosters a culture of data sharing and transparency and develops enterprise BI hierarchy linking strategic goals to project performance measures.

Implementation of BI generally evolves from paper-based systems to spreadsheet-based systems to relational database-based systems to web-based collaborative systems. The evolution can follow these steps or jump intermediate stages. In some cases, BI systems within an organization can have a foothold in multiple stages and can evolve through a combination of top down and bottom up approaches.

2.2. Leadership, governance, and change for successful BI application

The success of BI is dependent on both technical and organizational factors. Leadership, governance, and cultural change are foundational to fostering consistent, integrated, and useful BI processes. NCHRP 03-128 looked at the role of leadership, governance, and change management in successful BI adoption. It found that leadership is foundational to sustain a long-term commitment to BI, communicate the BI vision in the context of the organization's mission, and clear political and institutional barriers to BI.

From a governance perspective, without an enterprise-wide system to maintain and control consistent understandability and accessibility of data across the organization, BI cannot be fully integrated. The adoption and integration of BI processes and culture within an organization requires change at the organizational level. Change management is a systematic approach to dealing with the transition or transformation of processes and technologies. NCHRP 03-128 explores change management frameworks and principles that can be used to advance BI in transportation agencies. It also explores challenges to change and effective decision making, such as decision-making bias and techniques for overcoming bias.

2.3. BI tools and techniques

BI tools include one or more of the following three capabilities: 1) data preparation, 2) decision support, 3) complex ad-hoc analytics. Organizations initiating BI need data preparation and decision support tools at a minimum, while complex ad-hoc analytics can provide greater capabilities in more advanced BI organizations. Key differentiating factors across BI tools are found in the intended skill level of the users, the interoperability of the tools, and the usability across decision-making levels. Tools that leverage a cloud environment are less vulnerable to obsolescence and cost varies across tools and providers. As BI matures in transportation agencies, BI tools for transportation applications grow in specialization and advanced analytics.

The NCHRP 03-128 project provides information on types of analyses that can be used in transportation, including traditional statistics and newer analyses that complement traditional statistics. These include real time analysis; classification analysis; graph analysis; text mining; video and image analytics; and

prediction, neural networks, deep learning, and AI. It also looks at good practices for successful BI adoption and practices to avoid common pitfalls in BI adoption.

2.4. Data management

NCHRP 03-128 looks at how traditional data is maintained in transportation agencies and the need to transition to better usability. This requires a shift in data management toward open and accessible data. The research summarizes the current state of transportation data sources, specifies the characteristics of five data sets that offer new potential for analytics, describes the required evolution in managing data, introduces new tools to support data management, and presents the costs associated with storing and analyzing data.

3. IMPLEMENTATION STRATEGY

Advances over the past decade have made BI tools and techniques as well as cloud services a commodity that is now available to organizations with limited budgets and limited skills. In parallel, IoT devices, unmanned aerial systems, crowdsourcing, connected vehicles and citizens, and other technologies are generating a volume, velocity, and variety of data that offers data well beyond traditional sampling that is the mainstay of transportation agencies. The coalescence of these factors can shift a transportation enterprise from an engineering judgement-based decision making to a fact-driven, predictive and optimized decision-making organization. Examples of this shift are reflected in BI tools that allow analysts to optimize pavement preservation strategies through linear programming that reflects performance objectives and constraints, or machine learning tools that predict incident duration based on location, time, weather and other factors.

Yet, many local, regional, and State agencies are not currently able to leverage data efficiently because of policy, expertise, and data quality challenges or because of a or a poorly-orchestrated adoption strategy –leaving BI initiatives to falter and fail. Or worse, BI can become engrained within the organization without a noticeable return on investment –the outcome from unbridled investment in a flashy, embellished, and unproven product without a well aligned business case.

NCHRP 03-128 was tasked with developing an implementation plan that:

1. Provides recommendations on how to best put the research findings/products into practice;
2. Identifies possible institutions that might take leadership in applying the research findings/products;
3. Identifies issues affecting potential implementation of the findings/products and recommend possible actions to address these issues; and
4. Recommends methods of identifying and measuring the impacts associated with implementation of the findings/products.

These are discussed in this section as a general approach to implementation of the research findings.

3.1. Putting the findings into practice

Based on the research, stakeholder and panel workshop, and sessions at the TRB Conference on Performance and Data in Transportation Decision Making, the research team recommends several next steps to put the research findings and products into practices:

- Distribution of final report
- Webinars
- Conference presentations and workshops
- Pilot application of BI in 2-4 State DOTs

Distribution of final report

The NCHRP 03-128 Business Intelligence Techniques for Transportation Agency Decision Making Final Report is not the ‘traditional’ NCHRP final report that summarizes work by research task, but rather a document to facilitate use of the information and findings. The report provides information on the pathways, tools, and techniques for developing a BI-centric organization. The report can be used as a guide by agencies interested in initiating or expanding their BI effort. We propose the following distribution channels for the final report:

- Posting the final report on the TRB website.
- Including a write-up in the TRB and AASHTO email newsletters to get the information out to transportation agencies to implement the findings and recommendations.
- An announcement to be posted to AASHTO’s Transportation Management Hub which provides access to a suite of transportation management products.
<https://www.transportationmanagement.us/>
- An announcement in TRB ABC30 (Performance Measures), AHB10 (RTSMO), ABC40 (Asset Management), and ABJ20 (Statewide Data and IS) committee meeting newsletters and/or web presence.

Webinar

The NCHRP 03-128 research team developed a presentation for two consecutive sessions at the TRB Conference on Performance and Data in Transportation Decision Making. This presentation could be used as the basis for a series of interactive webinars supplemented by State DOT case studies. A webinar series could be sponsored by TRB, NOCoE, ITE, or others and would allow the information and findings of the project to be disseminated to a broader audience of transportation professionals and agencies. FHWA hosts a webinar series called Let’s Talk Performance, focused on transportation performance management that includes case studies and presentations by various agencies. This would be a natural sponsor for this webinar series or parts of it and the webinars are archived for access on the FHWA website. The series would cover the four topic areas outlined in the final report:

- BI adoption pathways and “maturity” stages;
- Leadership, governance, and change for successful BI application;
- BI tools and techniques; and
- Data management and trends.

Each webinar would also outline challenges and opportunities for BI in transportation agencies and provide case studies, inviting guest speakers from the suite of professionals interviewed or engaged in workshops as a part of this project. Transportation agencies that have implemented BI in one or more of their processes or are using BI at the enterprise level could present their initiatives and discuss lessons learned and agency efficiencies gained through BI.

The audience for the series would generally be transportation agencies but may change from one webinar to another depending of the focus and topic. For example, a webinar may focus specifically on case studies within a particular business area, such as asset management, or may be higher level with an emphasis on top down, enterprise BI initiatives that would have greater appeal to agency leadership. The series should be designed and presented to meet the audience needs of the sponsoring organizations.

Conference presentations and workshops

In addition to the proposed webinar, there are numerous opportunities for presenting the information at conferences and professional meetings. Interactive workshops can also be held for individual agencies interested in exploring the opportunities for using data to support decision-making at all levels of the organization. A variety of formats and offerings could be made by TRB to move the NCHRP 03-128 findings and recommendations from research to practice. Specific conferences to target are recommended and prioritized in Section 3.2.

Pilot application of BI in 2-4 State DOTs

The use of pilot projects in two or more State DOTs would provide a significant opportunity to put the research into application. Using the top down and bottom up models as the basis for pilot projects, a follow-on initiative to the research would provide an opportunity to test the methodology, identify challenges and resistance within transportation agencies, and expand the research through testing. This recommendation is discussed in more detail in the [Section 3.3](#).

3.2. Recommended presentations

As noted above, the research team recommends that information from the NCHRP 03-128 project be presented at a variety of conferences in the form of session presentations or as interactive workshops, depending on the meeting focus and time available. The findings from the project were presented in a three-hour format at the TRB Conference on Performance and Data in Transportation Decision Making in September 2019. The format used was a blend of presentation of the project approach and findings with interactive exercises and breakout groups. The presentation and format could be modified for a 30-minute session presentation or a full-day workshop. The following is a list of potential organization meetings in 2020 where the project could be presented.

Transportation Research Board

- July 11–14, 2020, Boston, Massachusetts. National Conference on Transportation Asset Management. Abstract deadline has passed but we can reach out to organizers. <https://trb.secure-platform.com/a/page/2020AssetManagement>
- September 21-24, 2020, in Atlanta, Georgia. 2020 International Conference on Winter Maintenance and Surface Transportation Weather. Abstracts due March 2, 2020. <https://trb.secure-platform.com/a/page/2020Weather>
- November 18, 2019, Boise, Idaho. National Tools of the Trade Conference - Sponsored by Transportation Research Board Committees ADA30 Transportation Planning for Small and Medium-Sized Communities, ADA40 Transportation Needs of National Parks and Public Lands, with the Community Planning Association of Southwest Idaho (COMPASS). Abstract deadline has

passed but we can reach out to organizers.

<http://onlinepubs.trb.org/onlinepubs/conferences/toolsofthetrade2020.pdf>

AASHTO Meetings

- May 26-29, 2020, Kansas City, Missouri. AASHTO Spring Meeting. <https://policy.transportation.org/aashto-spring-meeting/>
- November 4-8, 2020. Baltimore, Maryland. AASHTO Annual Meeting. The week long program offers transportation executives the opportunity to network and share the latest in industry policies and innovations. <https://policy.transportation.org/aashto-annual-meeting/>
- 2020 Annual Meeting. Committee on Transportation System Operations. Contact Gummada Murthy, Associate Program Director, Operations, gmurthy@aaashto.org
- July 13-15, 2020 in Hartford, Connecticut. The Northeast Association of State Transportation Officials (NASTO) 2020 Annual Conference. <https://nasto.org/2020-nasto-conference/>

ITE Meetings

- April 19-21, 2020, ITE Mid-Colonial District Annual Conference, Sheraton Inner Harbor Hotel Baltimore, MD. SID NEW Conference Chair, snew@gfnet.com
- May 13-15, 2020, ITE Northeastern District Annual Meeting, East Wind Long Island Wading River, NY, <https://ite-ned-annual-meeting.org/>. Organizers are: Amir Rizavi, Steve Eisenberg, and Luigi Casinelli
- May 3-5, 2020, Joint Midwestern and Great Lakes Districts Annual Meeting. <https://midwesternite.org/conferences/>
- June 28-July 1, 2020, Joint Western & Mountain Districts Annual Meeting, Hawaii. <https://www.ite.org/events-meetings/ite-calendar/2020-joint-western-mountain-districts-annual-meeting/>
- August 8-12, 2020, New Orleans, Louisiana. Joint ITE International and Southern District Annual Meeting and Exhibition. <https://www.ite.org/events-meetings/ite-calendar/itenola2020/>

ITS America Meetings

- April 27-29, 2020, ITS Heartland Annual Meeting, Hilton Iowa Events Center, Des Moines, IA .All abstracts must be submitted on or before Wednesday, January 8, 2020. Focus on ATIS, Big Data Applications, TIM, TSMO. <https://itsheartland.org/annual-meetings/>
- June 4-5, 2020, ITS New York 2020 Annual Meeting and Technology Exhibition
- September 27-29, 2020, ITSGA Annual Meeting, The Westin Jekyll Island, Jekyll Island, GA. Jenny Johnson, ITS Georgia Chapter President.
- Sun, Oct 4, 2020, ITS World Congress 2020, February 3, 2020 Call for Contributions Deadline

National League of Cities

- November 19-23, 2020, National League of Cities, City Summit. <https://citysummit.nlc.org/program/>. Target a conference workshop or a general Session.
 - Conference Workshops: Presentations, panels and discussions focused on the common issues cities face—from homeless and affordable housing to the future of work and a skilled workforce.

- General Sessions: Get inspired during exciting main stage programming, featuring motivational stories from well-known national leaders.

National Association of Counties

- May 13-15, 2020, Western Interstate Region Conference, Mariposa County, CA
- July 17-20, 2020, Annual Conference and Exposition

National Governors Association

- NGA 2020 Summer Meeting, TBA

The research team recommends targeting TRB, AASHTO, and ITE as the primary audiences, particularly their annual meetings or other cross-disciplinary conferences. As a secondary focus, it is recommended that subject specific meetings in business areas in which BI has been applied successfully, such as asset management, traffic operations, investment planning, and maintenance, be considered. These presentations would expand the understanding of BI in transportation to a broader audience and reinforce its use in specific business functions. The following conferences are recommended for presentations or workshops in 2020:

- TRB: July 11–14, 2020, Boston, Massachusetts. National Conference on Transportation Asset Management.
- AASHTO: May 26-29, 2020, Kansas City, Missouri. Spring Meeting.
- ITE: August 8-12, 2020, New Orleans, Louisiana. Joint ITE International and Southern District Annual Meeting and Exhibition.
- ITS Heartland: April 27-29, 2020, Annual Meeting, Hilton Iowa Events Center, Des Moines, Iowa.
- TRB Regional TSMO Midyear Meeting and AASHTO CTSO Annual Meeting – to be scheduled.

A number of these conferences have closed their call for abstracts and would require contacting the conference technical or program director for inclusion as a session or a half or full-day workshop.

3.3. DOT pilot projects

In order to implement the fourth recommendation above, the team proposes working with TRB staff to identify agencies that might be interested in applying the research findings/products as part of a pilot project. It is recommended that two to four State DOTs be identified who would work with the research team to develop and implement a BI program, applying both the bottom-up and top-down implementation strategies that moves them along the stages from paper-based to web-based collaborative BI applications.

The general approach would be completed under a separate NCHRP contract for implementation and would include the following process to apply the bottom up approach:

- Identify DOT with one or more specific pain points that would be addressed through BI.
- Confirm one or more champions within the agency to drive the BI pilot.
- Hold a planning workshop with the champion(s) and other agency personnel potentially involved or impacted by the pilot project to confirm target processes or pain points for the effort.

- Develop a general work plan for implementation following the bottom up implementation pathway focusing on content elements including leadership/governance, BI techniques and tools, and data management.
- Support the DOT in implementing the work plan.
- Conduct assessment on factors contributing to or detracting from success.

For the top down pilot project, the following approach would be followed:

- Identify a DOT whose executive leadership (enterprise or program level) are interested in initiating or expanding a BI initiative at the enterprise level.
- Hold a planning workshop with executive level leadership and other agency personnel potentially involved or impacted by the pilot project to confirm interest and commitment to the effort and identify an area of implementation for the pilot.
- Develop a general work plan for implementation following the top down implementation pathway.
- Support the DOT in implementing the work plan.
- Conduct assessment on factors contributing to or detracting from success.

It is preferable that one of the agencies selected for the top down or bottom up pilot is interested in applying both pathways and addressing more than one process or pain point. This could provide a pilot project for a hybrid implementation pilot.

The research team recommends working with TRB to develop an application process for State DOTs interested in applying for a TRB sponsored pilot project. The application process would consider:

- Level of support for BI at the executive level
 - Policies or formal commitments to BI
 - Funding or current BI initiatives
 - Commitment to performance management and data supported decision making
- Available resources
 - Staff capabilities and skills
 - BI tools and applications
 - Data storage capability
- Current level of BI applications and maturity
 - Current sources of data
 - Data governance and management policies
 - Defined BI processes
 - Ease of access to data across business areas
 - Integration and management of data
- Level of commitment by one or more business areas
 - BI champion
 - One or more clearly defined pain points
 - Current initiatives to streamline and automate processes

3.4. Addressing issues affecting implementation

Issues affecting potential implementation of the findings/products include:

- Organizational resistance
- Funding
- Understanding the process
- Staffing and capability constraints
- Obsolescence of tools
- Political barriers

These are discussed below with possible actions to address the issues.

Organizational resistance

In agencies where there is an absence of executive level commitment to BI, or where change is not accepted as part of the culture, there may be organizational resistance to evolving processes toward BI. Agencies that are comfortable in the way things have always been done, or are skeptical of the benefits of data enabled decision making or automated processes may resist the application of BI in decision making, management, and operations. The best way to overcome organizational resistance is through pilot projects that demonstrate the benefits – cost savings and better decision making. A simple application that uses data to advance the agency’s mission and objectives can help skeptics see how their jobs can be simplified and results enhanced. In agencies with organizational or cultural resistance, it is best to find pain points that can be addressed through simple BI applications and follow a bottom up pathway to demonstrate effectiveness.

Funding

New enterprise-level BI initiatives can be costly in financially strapped agencies. Funding for BI can inhibit new BI projects that may require new data sources, expanded computing capabilities and data storage, and staffing or consulting services to support the program. Agencies concerned with cost should consider potential cost savings in automating decision support processes to realistically consider the financial benefits and opportunities. This is also an issue that may be best addressed through a bottom up approach, implementing low cost applications and evaluating the savings and benefits. For example, clearly defining decision processes and applying simple spreadsheet-based analysis to existing data sources provides a low-cost approach to BI that may provide a significant return on investment, yielding greater support for expanded applications.

Understanding the process

Transportation agencies have not had as much experience in BI applications as other industries, particularly private-sector industries. A lack of understanding of BI, what it is, and how it applies to the management and decisions of transportation agencies, can create a barrier to BI adoption. Sharing information on the benefits and opportunities of BI in transportation agency decision making, including transportation industry case studies, tools, and techniques, can support agencies’ acceptance of BI and encourage adoption. Outreach efforts such as those recommended in this document (TRB sponsored webinar, distribution of final report, presentations and workshops, and pilot projects) can help transportation agencies understand how BI can be used to support and enhance decision making at all levels of the organization.

Staffing and capability constraints

Transportation agencies have traditionally focused on planning, designing, constructing, and maintaining transportation systems and have hired planners and civil engineers to carry out those functions. BI requires new skill sets and training, making it difficult to find the staffing and capability within existing personnel. Business managers, data and computer scientists, process experts, statisticians, and others versed in the nuances of BI may not currently exist within an agency, or may be limited in focus and availability. Understanding the staffing needs of a BI organization and adding capabilities over time can enhance an agency's ability to pursue BI.

Obsolescence of tools

A number of transportation agencies have initiated BI initiatives, starting with simple spreadsheet applications and working to streamline and automate analytics and decision making. One of the issues that impacts successful applications is the speed at which hardware and software change, as well as the sources and format of data. In order to maintain an effective, mature BI program, agencies must update and evolve hardware, software, and data management. As the volume of data increases, the need for greater computing power and data storage systems becomes essential. Many agencies are moving to the cloud to address these needs. Decisions to invest in proprietary software can also add to the issue of obsolescence as agencies become locked into specific tools or are left unable to update software or move to more advanced analytics packages. It is important to consider the ongoing investment and maintenance needs of the tools selected to support BI to understand future investment and upgrade needs.

Political barriers

An interesting obstacle to BI identified in the research is that of political barriers. Agencies that have traditionally made decisions based on the political motivations of elected and appointed officials may be resistant to more transparent, data-supported decision-making processes. This can be overcome through bottom up applications in nonpolitical decisions as well as by sharing successes and cost savings in areas of importance to the public and elected officials.

3.5. Methods of identifying and measuring impacts of implementation

As transportation agencies advance the use of BI in decision making, it is important to track the success of implementation through top down, bottom up, and hybrid pathways. This section recommends several methods of identifying and measuring the impacts associated with implementation of the findings/products of NCHRP 03-128.

One way to look at the level in impact of this project is to evaluate the extent of outreach of the final products. Although this is more of an output measure it can be used to assess the distribution of information and agencies' potential familiarization with BI. This would include the number of presentations associated with the project findings, number of locations where the products are shared and announced, and the level of interest by State DOTs to participate in the pilot projects.

Measuring the direct outcome of the project on the implementation of BI by transportation agencies is more difficult and requires review and analysis over time. An initial evaluation of DOT organizational charts to determine the prevalence of offices of performance management and the role of IT

departments in an agency may indicate the level of commitment to BI and data supported decision making. A survey of DOTs could provide an indication of the use and saturation level of BI in transportation agencies and a follow up review and survey could be conducted after the recommended implementation activities are completed to determine how effective the outreach and pilot projects are to supporting BI applications. The proposed pilots provide an opportunity to evaluate DOTs that participate in the pilot projects. There are a number of metrics that could be used to determine the impact of implementing the guidance of NCHRP03-128 in the pilot applications. These include:

- Evaluation of steps executed for each of the pathway steps
 - Level of application
 - Effectiveness of execution
 - Results of each step
- Level of acceptance
 - Within the business function
 - Across functional areas
 - Enterprise-wide
- Number of processes upgraded or automated
- Time and cost savings associated with upgraded processes
- Ease of access to data across business areas
- Integration and management of data
- Change in trust and cooperation across functional areas

4. RECOMMENDATIONS FOR ADDITIONAL RESEARCH

A key outcome from the stakeholder workshop (Task 6) as well as interviews with agency decision makers (Task 3) was the identification of gaps in agencies' ability to adopt BI practices and tools. These gaps are outlined in this section as the basis for recommending additional research. These recommendations are summarized and insights are offered on how additional research might be pursued with the TRB infrastructure as well as by other federal agencies and associations. Section 4.3 discusses the priority research recommendations from these finding.

4.1. Gaps identified in stakeholder workshop

The NCHRP 03-128 project team conducted a stakeholder workshop on June 26th, 2019 at the Arnold and Mabel Beckman Center of the National Academies of Sciences and Engineering. The goal of the workshop was to engage state, MPO, and local agency decision makers to review, clarify, and enhance the content developed to inform business intelligence (BI) adoption within transportation.

The workshop brought together individuals at the executive and program level that are decision makers and IT service managers, including 12 individuals that represented six overlapping areas of expertise among nine State departments of transportation, two local departments of transportation and one metropolitan planning organization. Additionally, five members of the NCHRP 03-128 panel and the project manager participated in the workshop, totaling 18 contributors. The following are some suggestions for further guidance beyond the scope of this project that would support the advancement of BI in transportation agencies.

Data to decision

Develop more detailed guidance on the steps needed to get from data to decision. By and large, clearly defined, formalized decision processes are not available in transportation agencies. The human and technology-based data is growing in richness. The documentation of decision processes and linking these processes to data will improve decision making.

Making the BI business case

Develop a clear business case to support the implementation of BI at the enterprise level. Stakeholders expressed a need to know how to sell BI to executives; tell them in 5 minutes how data is going to help their organization while avoiding unnecessary jargon. The business case should clearly communicate the purpose and benefits of new BI tools to executives from the perspective of business functions and IT.

Considerations for application selection

Technology is changing too rapidly for decision makers to keep up. Executives are in danger of being sold on an advanced tool from a vendor that they lack the foundation to use. Cost effective applications that provide flexibility and future expansion are important to a sustainable BI program. Guidelines on the selection of tools and the level of technology investment is needed to support informed decision making. This should not focus on specific products or applications but discuss the principles and considerations for the selection of tools and technologies.

Data sources

When getting data from external sources there are issues of transparency and control that must be addressed. Further research and guidance are recommended that speaks to data quality management, cloud data access controls, data ownership, and why data management is important.

Workforce development

With a shift from traditional workforce requirements focused on planning, designing, constructing, and maintaining the transportation system to BI processes, more specialized data-focused knowledge, skills, and abilities (KSA) are needed to support BI initiatives. A number of DOTs have created Chief Data Officer positions to support BI and performance-based management initiatives, and new requirements are being added to existing positions across business areas. More needs to be understood about the positions and KSAs required at all levels of DOTs to transition to BI-centric organizations.

Coordination across applications

Participants in the workshop talked about how they are beginning to use reliability measures in their agencies; however, they noted that there is no clean process that links the performance measures to processes that in turn would affect the direction of the measure. There is a need to link measures with BI processes that lead to desired outcomes and objectives. Sample processes could be developed in subsequent research to integrate performance measures and performance data into actionable information.

Pilot projects

Workshop participants suggested one way to overcome obstacles to BI within transportation agencies would be through pilot projects. These would be similar to the implementation recommendation outlined in Section 3.3 above. Real world applications are extremely effective in demonstrating the value of BI and providing an opportunity to address a variety of issues and potential obstacles.

Sharing lessons learned

Education and sharing successes and lessons learned are essential to creating BI centric transportation agencies. Formal education through webinars, workshops, and guidance documents can improve the adoption of new processes through enhanced understanding. Sharing processes and lessons learned less formally can also provide support for BI adoption. It is recommended that in addition to the webinars and workshops identified in the implementation strategy above, a website be developed to serve as a sharing platform among transportation agencies exploring BI applications. The site could be developed and housed through AASHTO or TRB, similar to the NOCoE site, to allow agencies to post their analytical processes, share data, and provide lessons learned and success stories.

4.2. Research needs from agency interviews

As part of this project, the research team interviewed representatives from eight transportation agencies to gain insight into the extent of use of BI, at what level (enterprise, program, and operations), and in which areas (business processes, strategic and investment planning, asset management, operations, etc.).

Each interview was conducted by two or more members of the research team and covered the following questions:

- What areas of the agency are currently using BI in their decision making?
- Is BI more commonly used in capital investment decisions or systems operations and management, asset management, or other areas?
- At what levels of decision making are BI metrics currently being used?
- What are the current or former technology solutions your agency has been using?
- How is data organized to support BI across the organization?

Additional agency-specific questions were asked based on responses and the focus area and responsibilities of the interviewees. A number of issues were raised that are suggested here for follow on research.

BI processes

In general, the agencies all had increasing sources of data for management and operations, although formal processes for data-driven decisions were not well developed. There was a general interest in guidance on how to develop processes that can be used to take data from its raw form to actionable information and the steps for decision making.

Tools and software

A number of agencies have developed tools inhouse or in cooperation with universities in their state specific to their information needs. Some agencies are using tools available through FHWA. As BI software vendors adapt to the potential demand in transportation agencies, more agencies are considering or implementing vendor applications to support decision making. There is an interest in future research that develops a list of currently available BI applications and sources by functional area for use by transportation agencies. In addition, guidance on selecting applications would help agencies determine the best tools for their needs. This would include considerations for selection, such as ease of use, ability to migrate data and processes to different applications, ownership of data, applicability to needs, data formatting, and management requirements.

Data management

The vast majority of agencies have developed application-specific databases within their divisions or offices. These are generally siloed with little or no integration of data across the enterprise. The increasing amount of data available through ITS devices, sensors, third parties, and newer sources is moving more agencies to consider cloud-based storage options. This migration provides an opportunity for agencies to look at the array of data sources and develop integrated data warehouses for use across the enterprise. This will require formal data management and governance planning, which generally is not in place but is being considered in a few agencies.

4.3. Research priorities

Based on the research needs identified in this project, the following research priorities are recommended.

Synthesis of tools and data

A synthesis of common data sources, applications, and tools to support BI in transportation agencies should be developed to support DOTs in exploring BI opportunities for their agencies. The synthesis should include case studies and references to peer agencies who are using or have previously used various tools, technologies, and data sources. Identifying contacts for these case studies would also support an informal peer exchange structure. This work could also include recommendations on key considerations for practitioners in selecting new tools, technologies, third-party data, or data storage and management platforms.

DOT pilot projects

Pilot projects discussed above in Section 3.3 provide the best opportunity to explore the application of top down and bottom up pathways for implementing BI in transportation agencies. It is recommended that TRB implement pilot projects in two to four State DOTs as outlined above.

BI sharing platform

Opportunities and platforms for sharing analytical processes and data, such as websites, peer exchanges, or user groups can effectively foster sharing of BI successes and applications across states and agencies. It is recommended that a website, similar to AASHTO's TSMO website, be hosted by AASHTO to serve as a repository for BI guidance and to share BI analytics, processes, and tools.

Workforce development

It is recommended that a research project similar to the NCHRP 20-07/Task 408 *Transportation Systems Management and Operations (TSMO) Workforce Guidebook*, that looked at the changing workforce needs to support TSMO in transportation agencies, be undertaken to support and advance BI. The research should look at KSAs needed at each level of the organization, identify new and emerging positions to support BI, and resources available to support the evolution of positions and KSAs in transportation agencies to fully implement BI.

Secondary recommendations

In addition to the priority recommendations above, the project team recommends the following gaps be considered for additional research. Each of these is discussed in more detail in Sections 4.1 and 4.2.

- BI process guidance – provide guidance to help agencies develop processes and associated analytics and applications to implement BI.
- BI business case – develop a business case for using BI in transportation agencies and provide guidance to organizations for developing a business case to promote BI within their agency.