# Quality Processes for Bridge Analysis Model

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# Structural Analysis Models

- Bridge design involves the use of structural analysis models of varying degrees of complexity including:
  - 1D line girder analysis
  - 2D analysis using line elements (with/without plate/shell elements)
  - Linear-elastic finite elements
  - Strut and tie analysis (STM)
  - Nonlinear finite element analysis

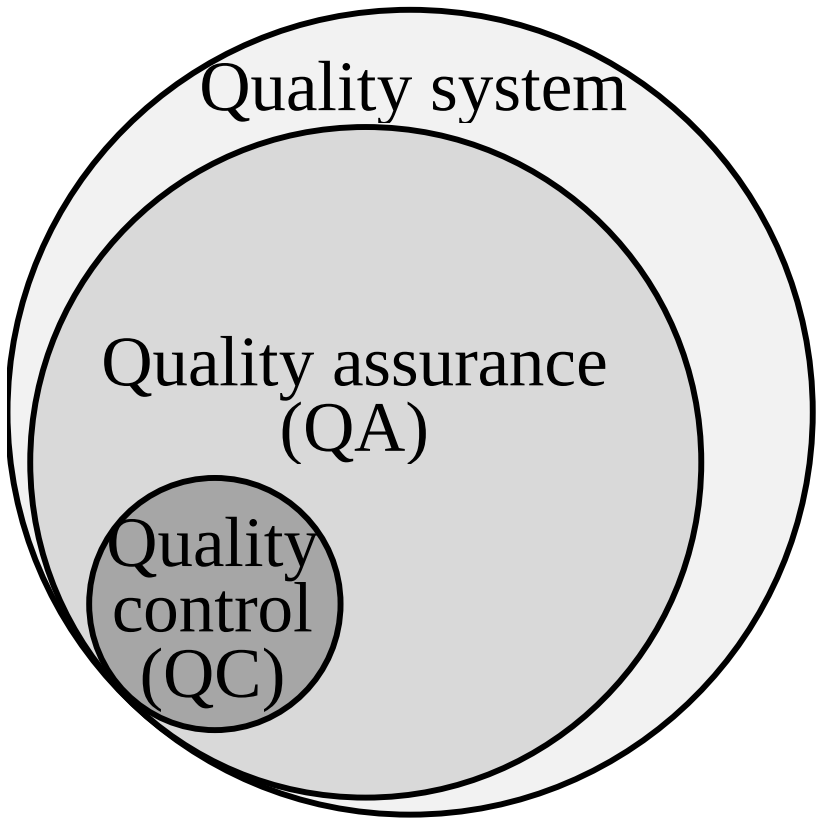
# Objectives

- Identify and document state DOT practices for quality processes of bridge structural analysis models.
- Document the processes for
  - identifying appropriately qualified staff (in-house and consultants)
  - choosing an appropriate analysis method and software
  - validating the analysis software
  - modeling a bridge structure with proper approaches and assumptions
  - verifying the analysis results
  - reconciling discrepancies between independent models

# Methodology

- Literature review
- Online survey of 51 DOTS (50 states and Washington D.C.)
  - **100% participation rate** is achieved.
- Follow-up interviews with five selected state DOTs

# Quality Processes: QA and QC




- QA activities cover virtually all of the quality system while QC is a subset of the QA.
- A good QA/QC program is **deliberate** and **systematic** to reduce the risk of introducing errors and omissions into an analysis.
- **Support of the upper management** in the development, documentation, and use of a QA/QC program is important.
- **Experienced, competent staff** and **good relationships** across disciplines are also important.

# QA/QC in Bridge Structural Modeling

- An indispensable component: **Verification** and **Validation (V&V)**

Verification ≠ Validation
and should not be used interchangeably.

- Verification deals with ***'mathematics'***
- Validation deals with ***'physics'***

- Verification is also described as *'solving the equations right'*
- Validation is also described as *'solving the right equations'*

# Verification

- *Definition:* 'the process of determining that a computational model accurately represents the underlying **mathematical** model and its solution'.
- *How to do:* comparisons of the computational solution with other mathematical solutions including
  - Analytical
  - Highly accurate numerical solutions
  - Manufactured solutions, etc.
- *Sample verification activities in bridge engineering:* sanity checks, independent calculations, line-by-line checking, refined analysis.
- In verification, the relationship of the simulation to the real world is *not* an issue.

# Validation

- *Definition:* 'the process of determining the degree to which the model is an accurate representation of corresponding **physical experiments**'.

- *How to do:* comparisons of the computational solution with **experimental data**.

- In validation, the relationship of the simulation to the real world *is* the issue.

# Other QA/QC Activities

- *Sensitivity Analysis:* is the process of discovering the effects of model input parameters on the response quantities of interest.
  - useful for determining the level of uncertainty and its effect on an analysis.

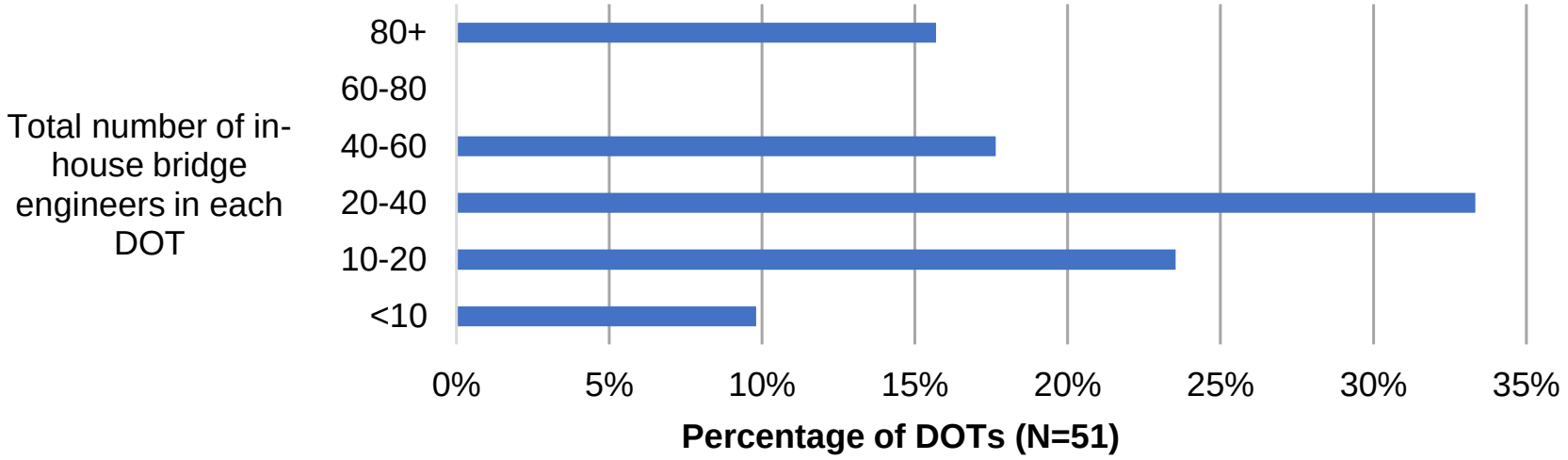
- *Calibration(!):* is to employ explicit tuning or updating of model parameters to achieve improved agreement with existing validation experiments.
  - calibration determines only the model's fitting ability, not its predictive capability.
  - due to superimposing of errors, the engineer may get good correlation for a wrong model, defined by incorrect input parameters.
  - Such a situation is often detected when the model is used for a different case with changed input conditions.

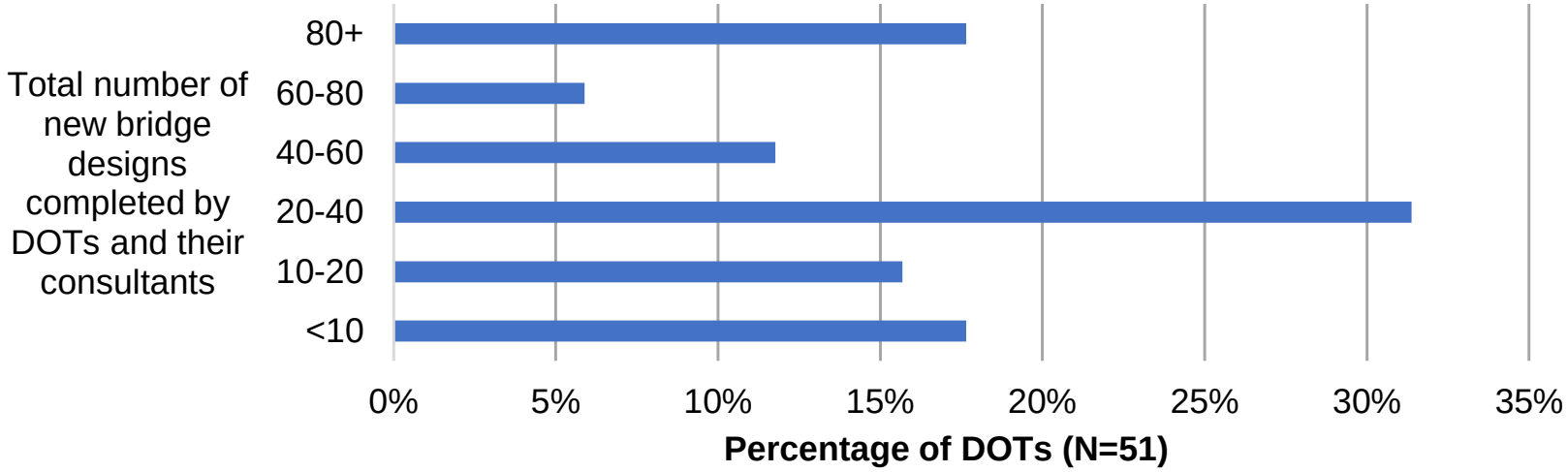
# State of Practice in the U.S.

- 25-question online survey was sent to each DOT's voting member in the AASHTO Committee on Bridges and Structures (COBS).
- Survey had three sections:

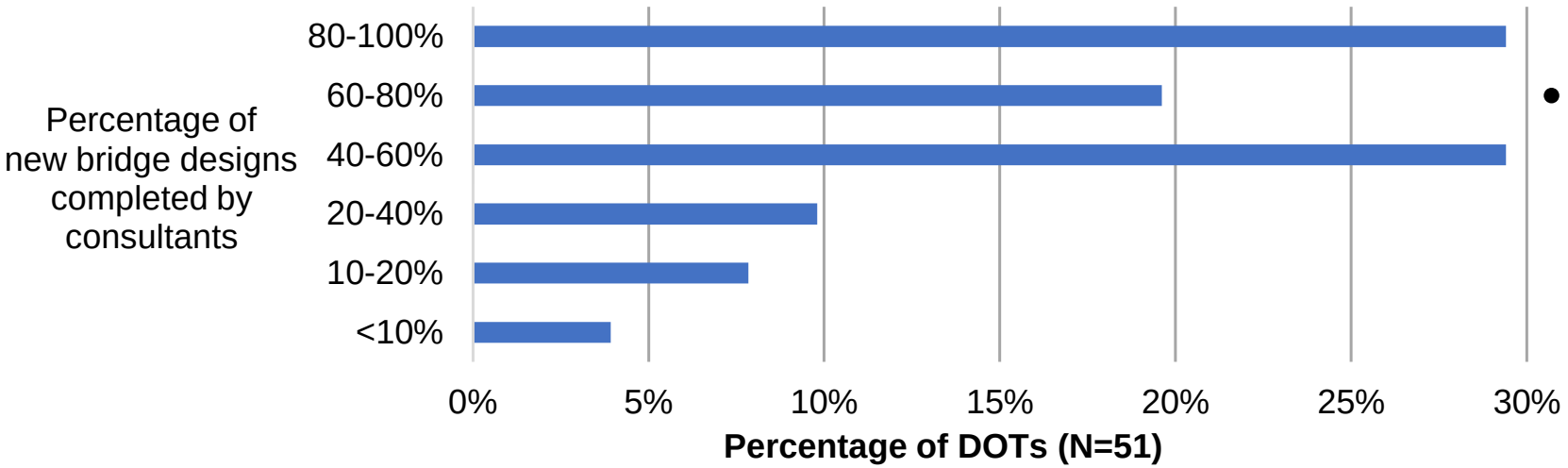
1) Quantity of bridge design and evaluation projects undertaken
2) Quality processes for bridge design projects undertaken by consultants
3) Quality processes for bridge design projects performed in-house

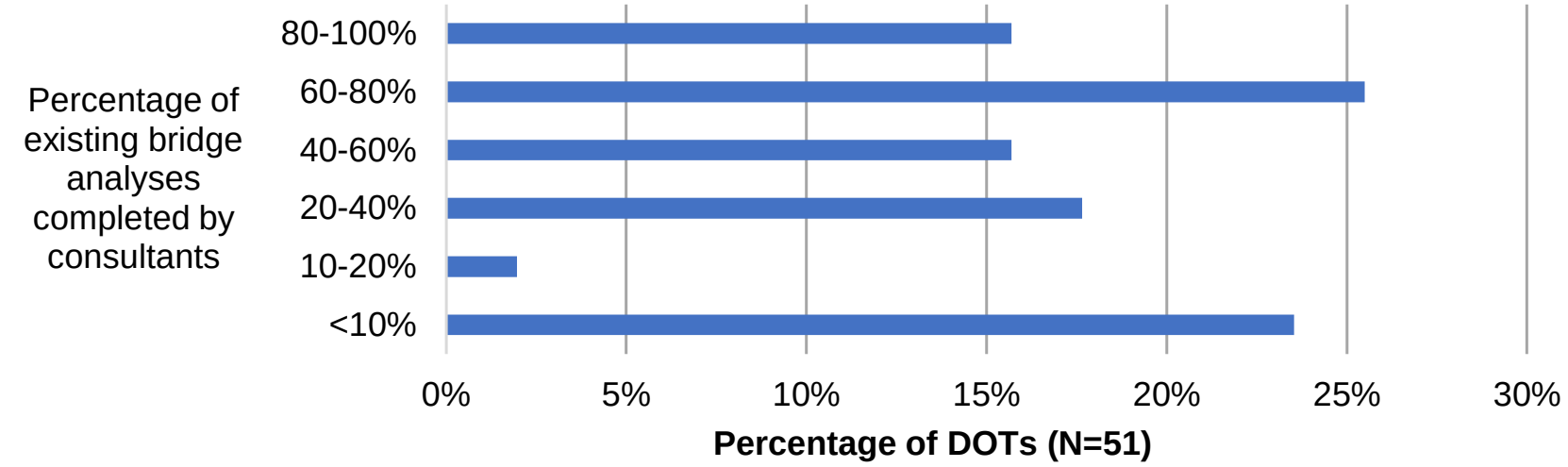
# 1) Quantity of Bridge Design & Evaluation Projects



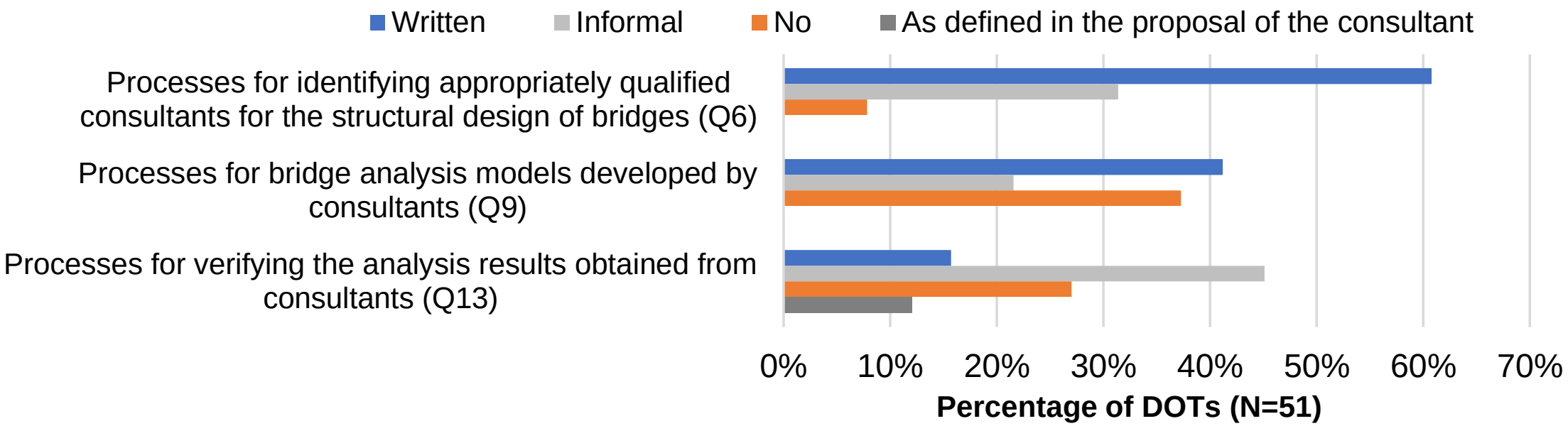
# 1) Quantity of Bridge Design & Evaluation Projects

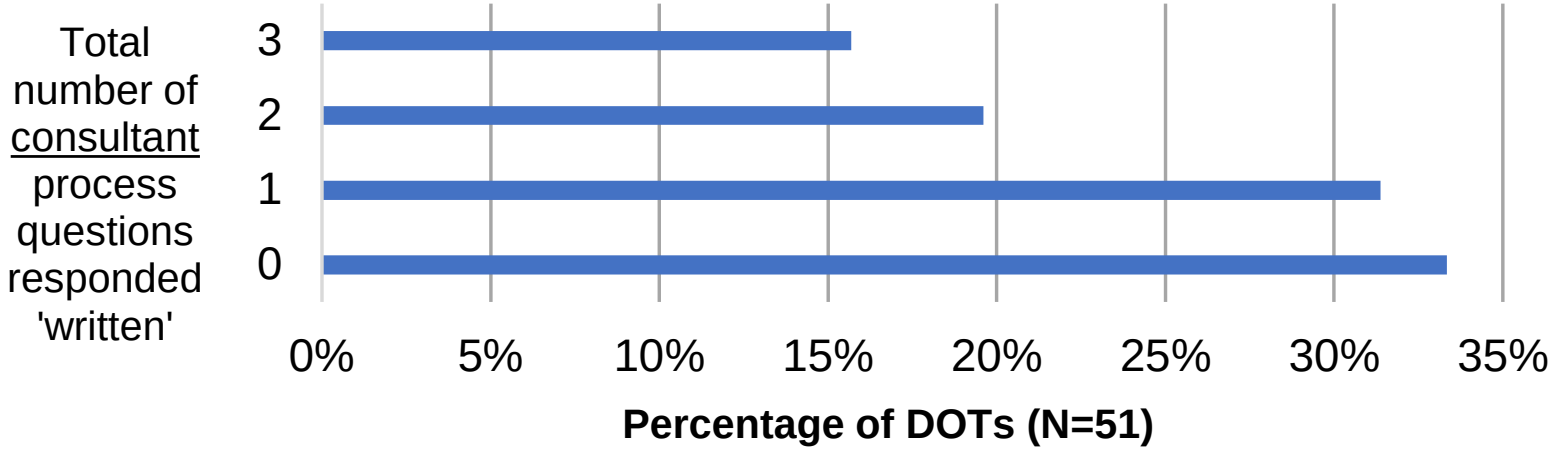



- Average percentage of
  - new bridge and bridge replacement designs assigned to consultants is **59%**
  - existing bridge analyses, including load ratings, assigned to consultants is **47%**

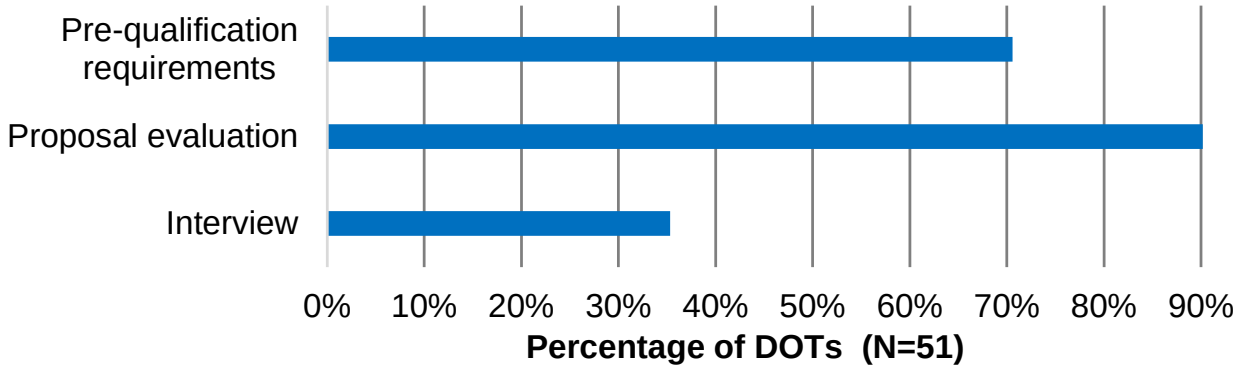
# 2) Quality Processes for Consultants

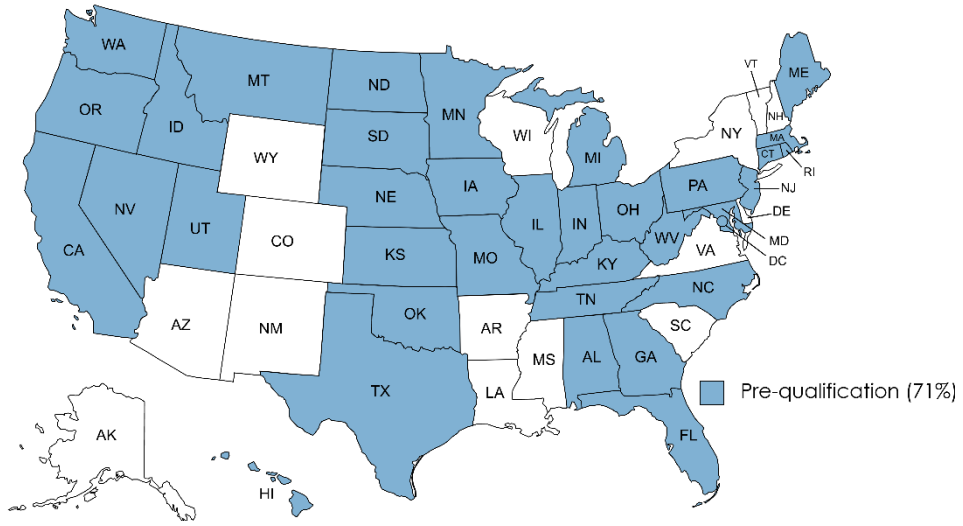


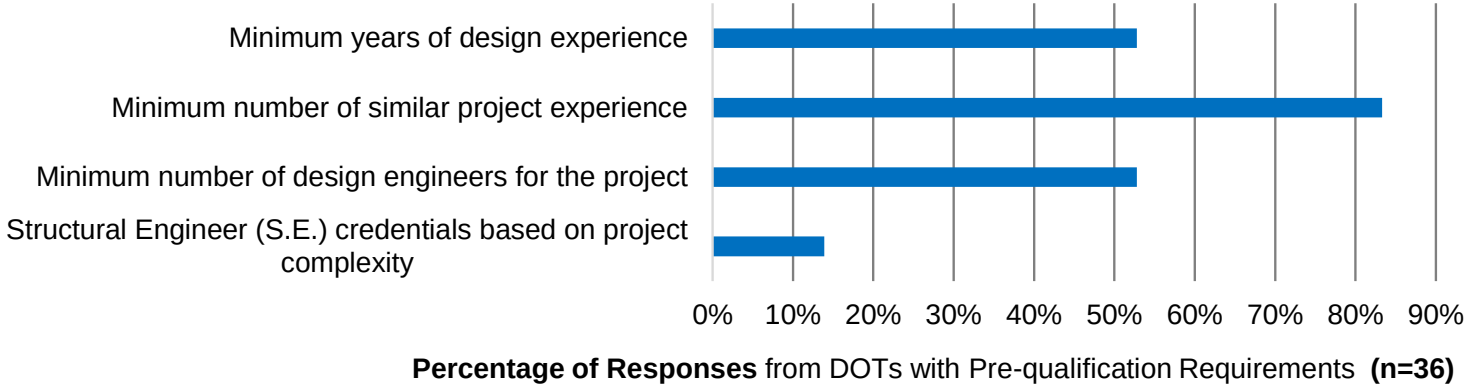



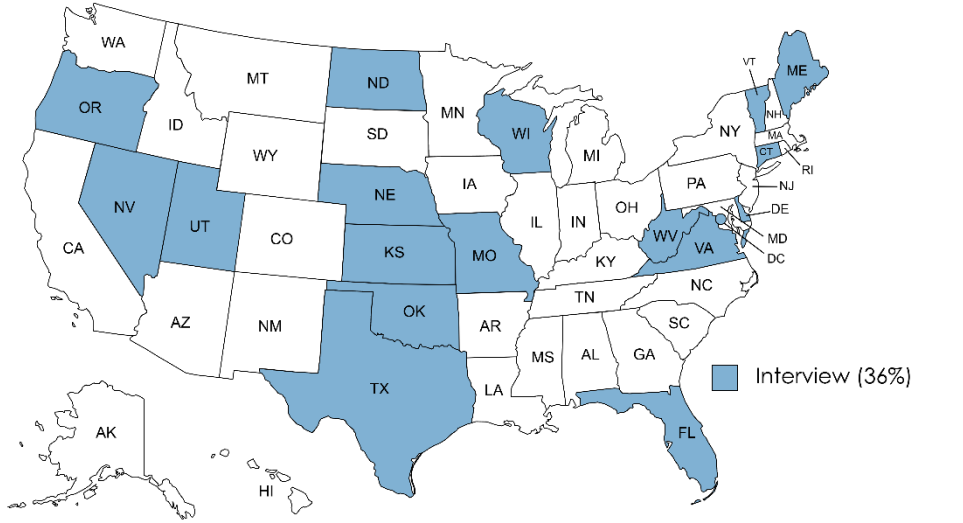
# 2) Quality Processes for Consultants

- Processes for selecting appropriately qualified consultants:



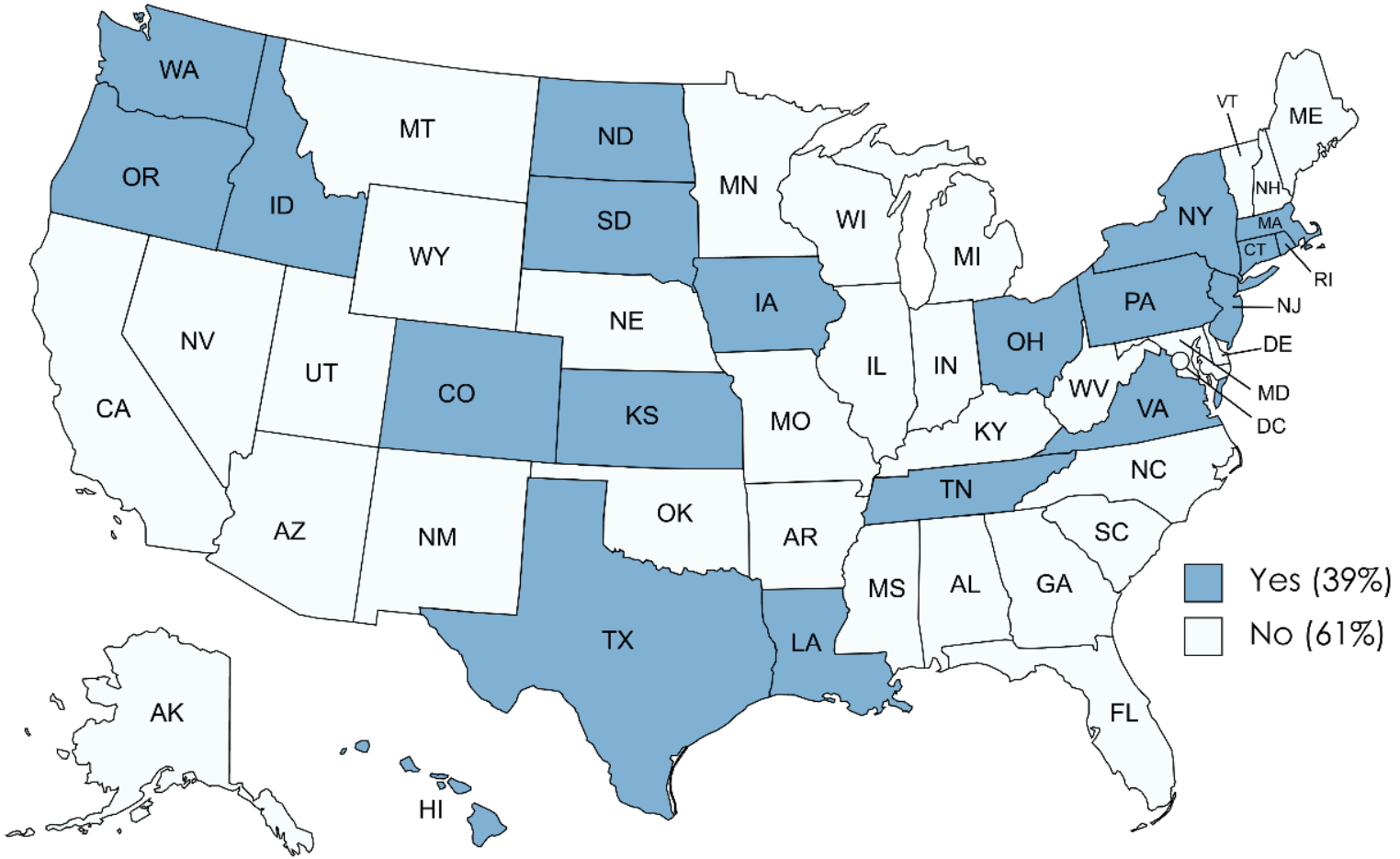



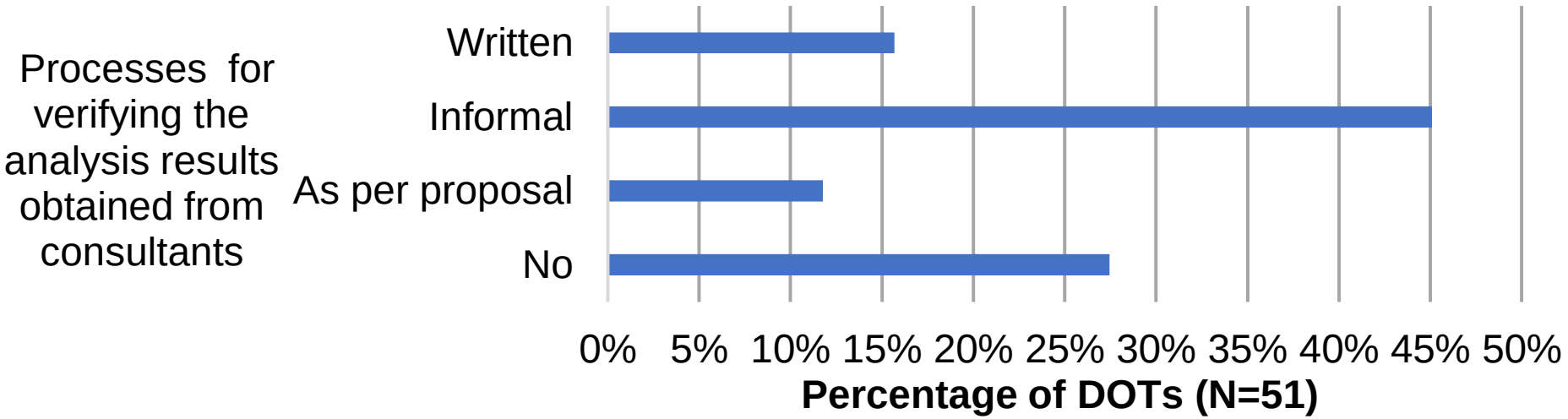
# 2) Quality Processes for Consultants

- Approved software list for bridge modeling and analysis:



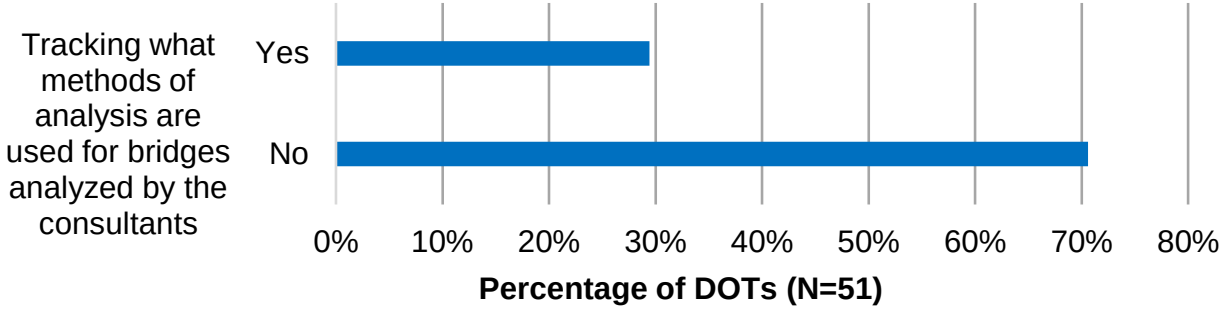
# 2) Quality Processes for Consultants

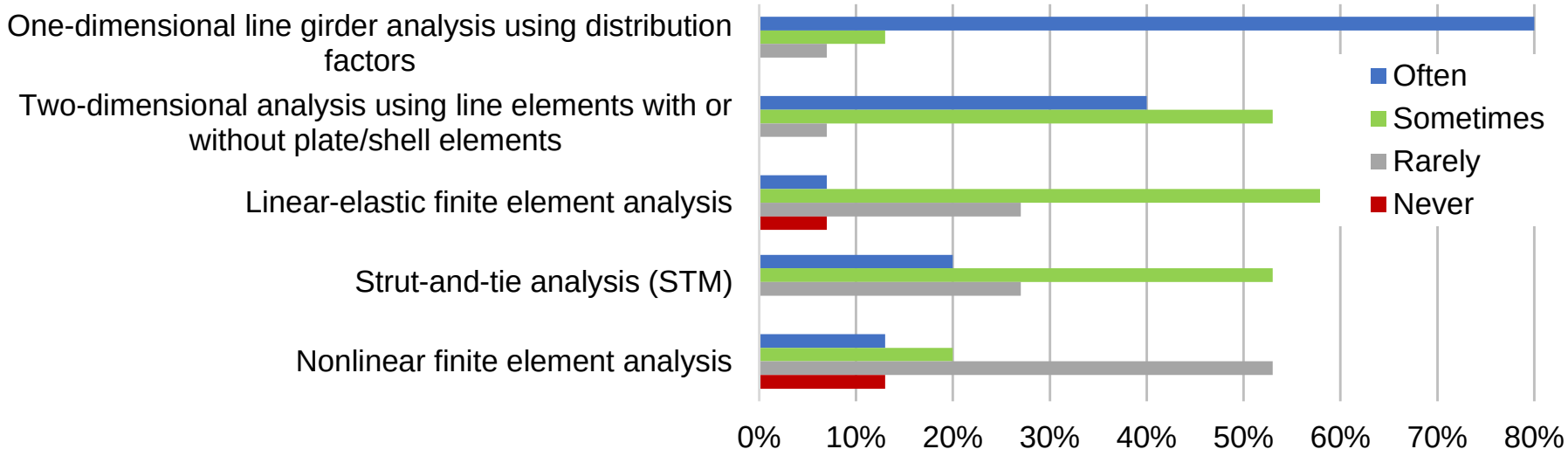
- DOT processes for verifying analysis results obtained from consultants



# 2) Quality Processes for Consultants

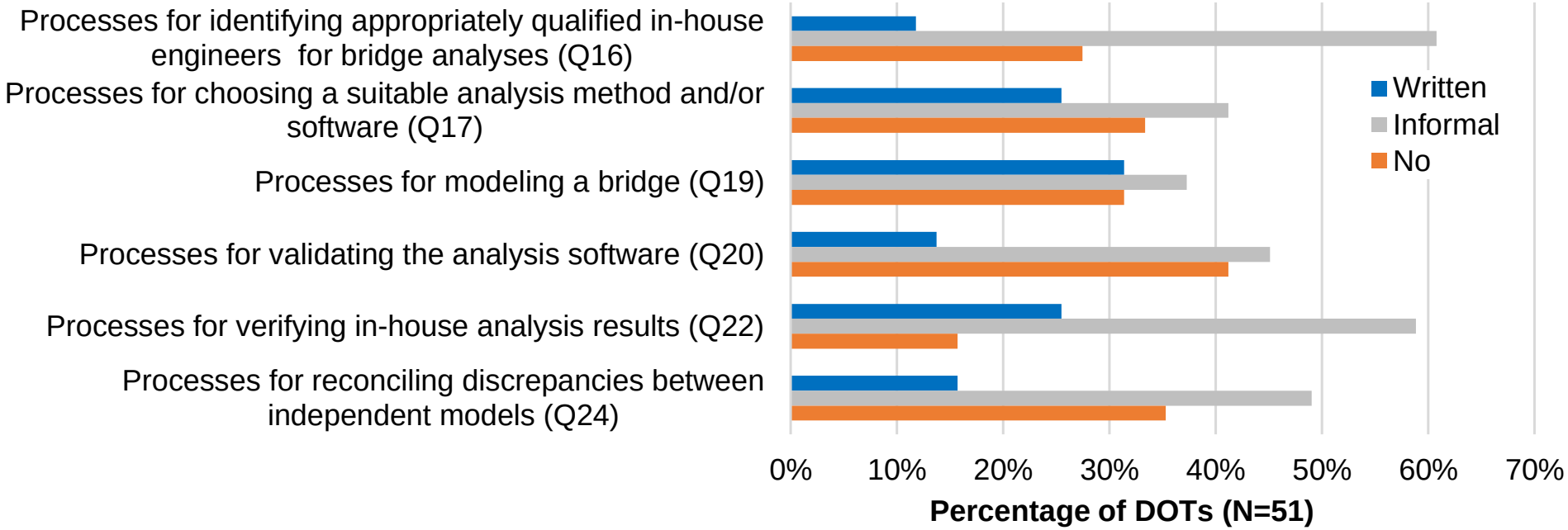
- DOTs which track what methods of analysis is used by consultants

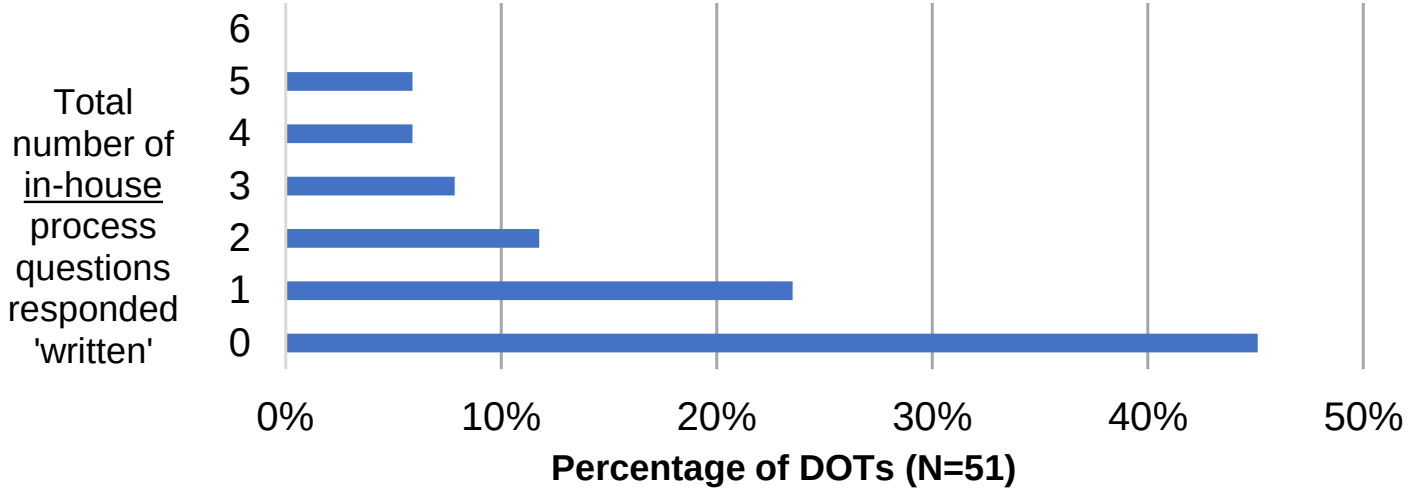



**Percentence of Responses** from DOTs which track what methods of analysis are used for bridges analyzed by consultants **(n=15)**

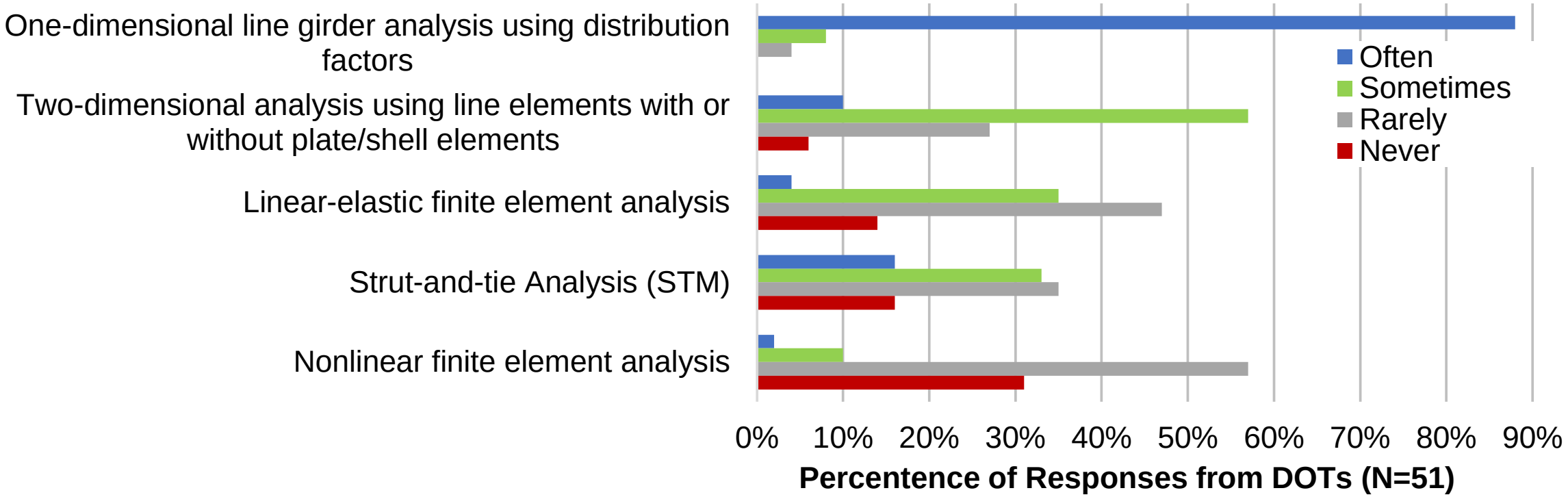
# 3) Quality Processes for In-House Projects



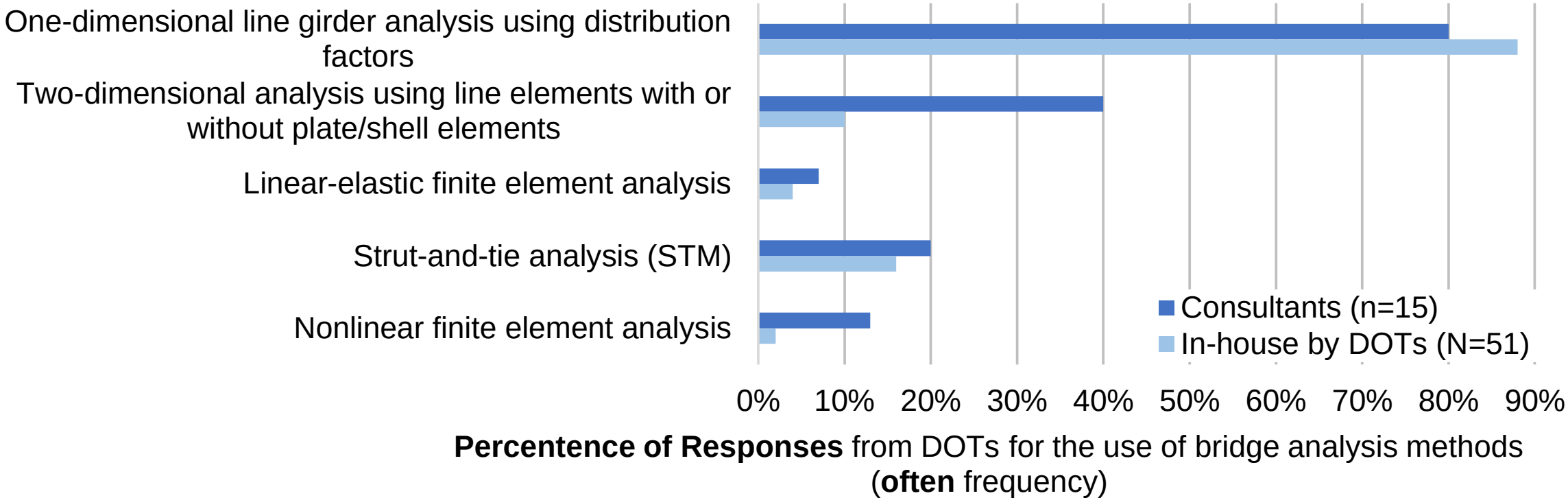
# 3) Quality Processes for In-House Projects

- Methods of analysis used for bridges analyzed **in-house** by DOTs



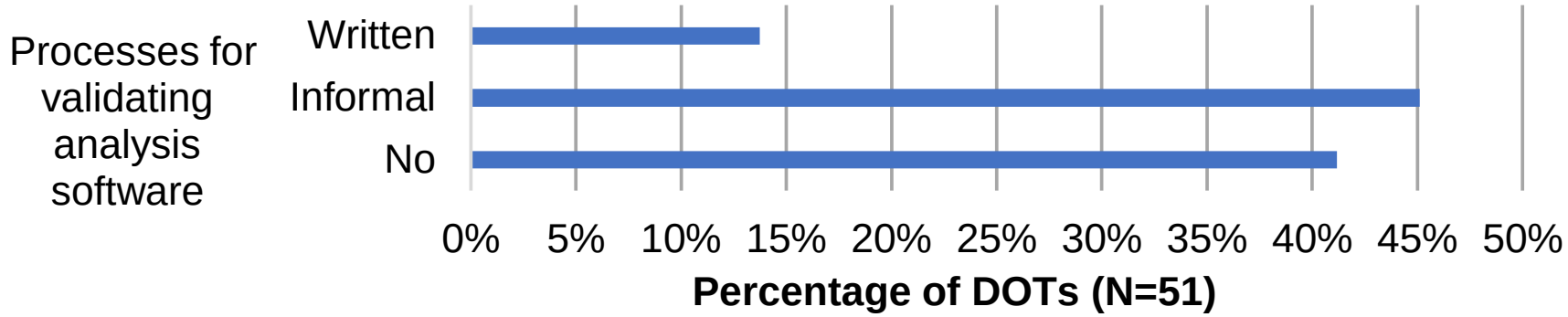
# 3) Quality Processes for In-House Projects

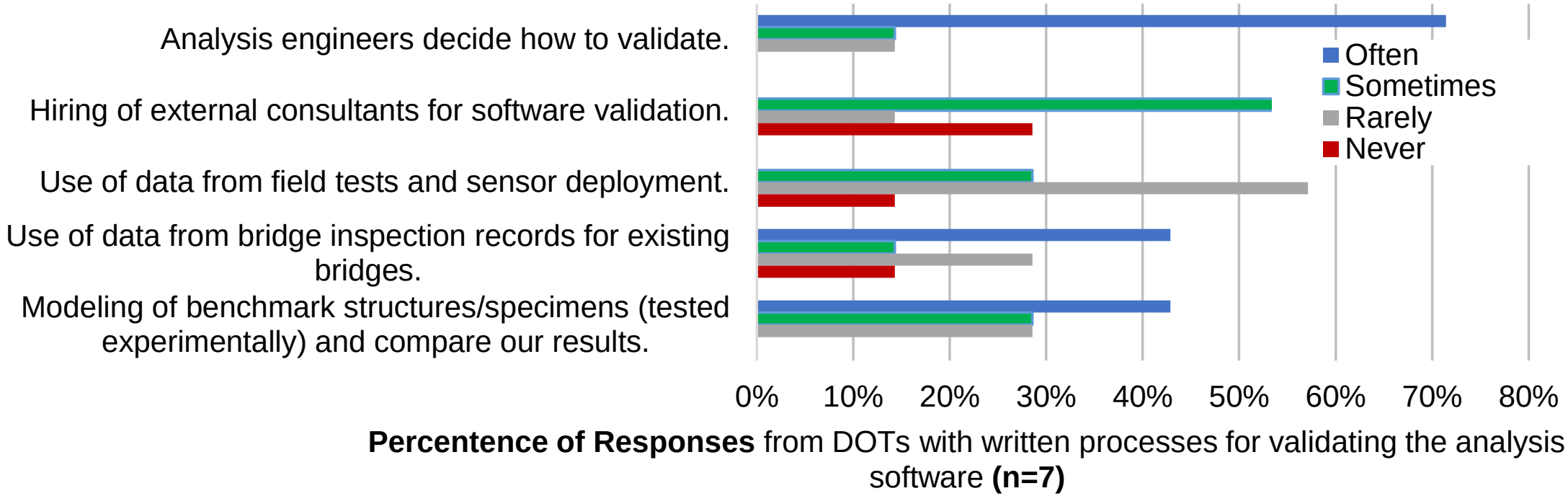
- Methods of analysis used for bridges: **in-house** vs. **consultants**



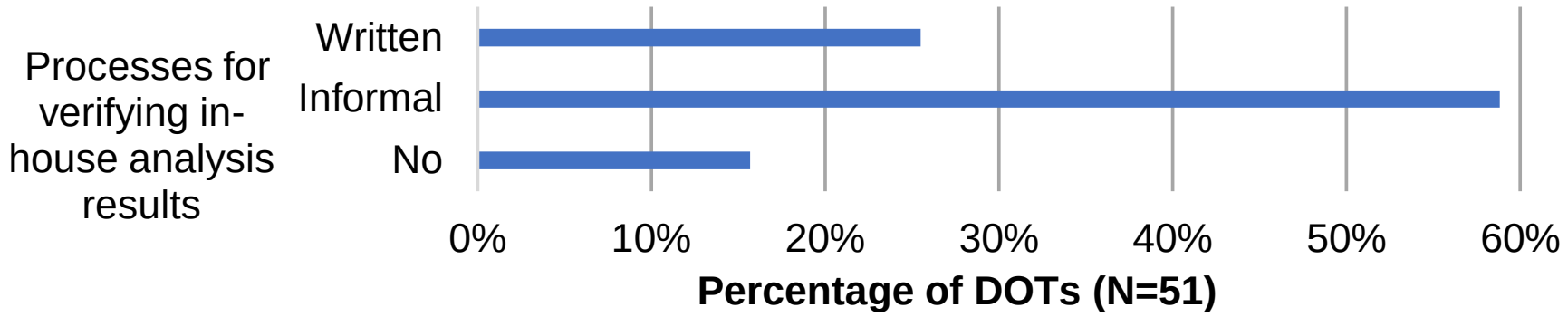

**Percentence of Responses** from DOTs for the use of bridge analysis methods (**often** frequency)

# 3) Quality Processes for In-House Projects

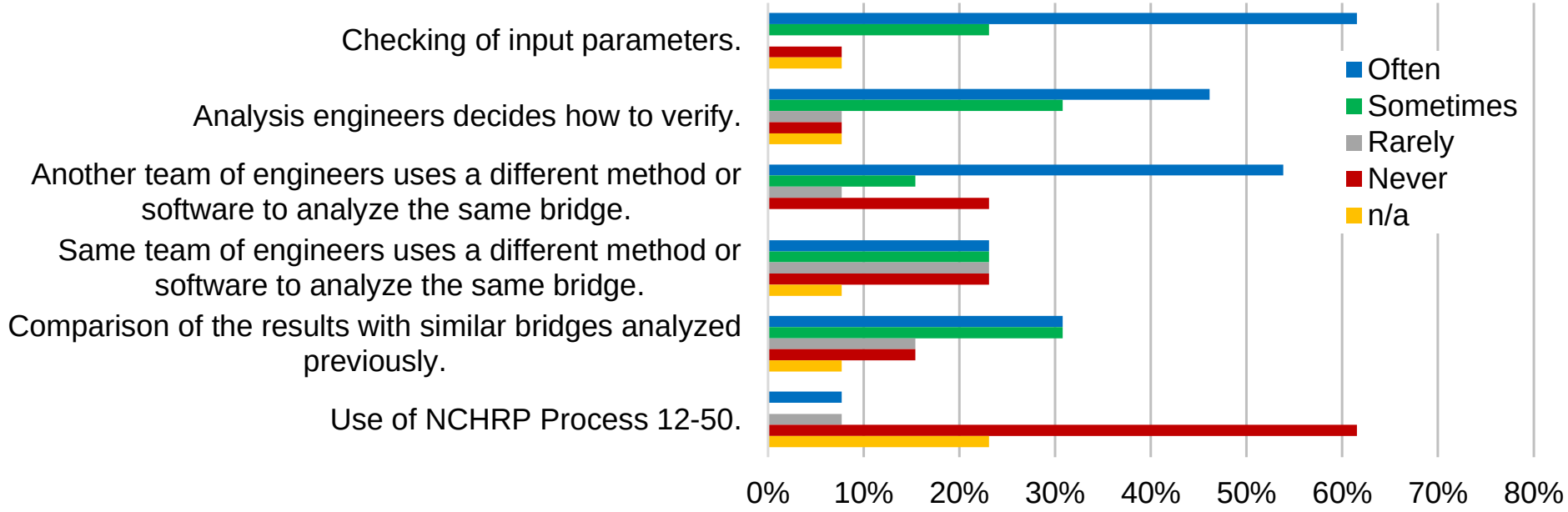


# 3) Quality Processes for In-House Projects

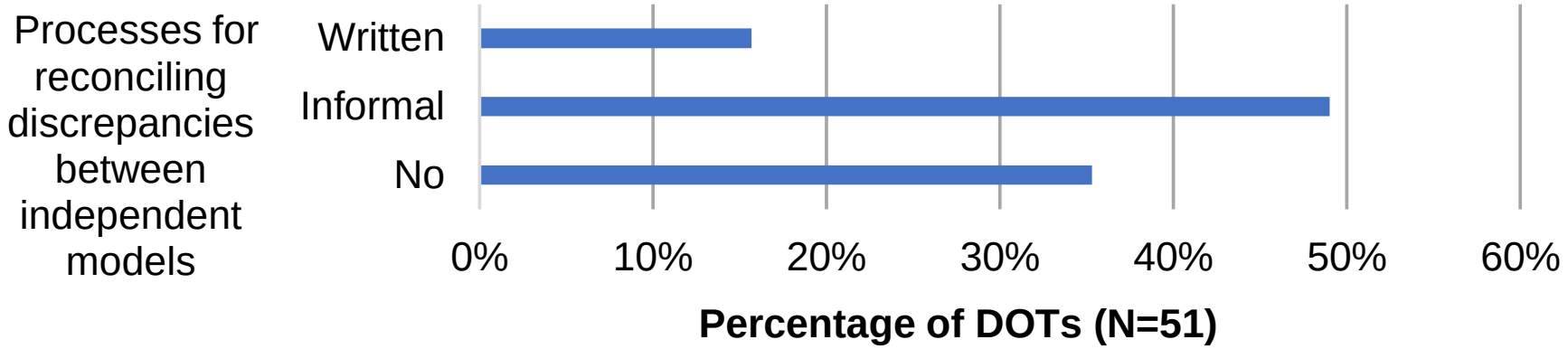


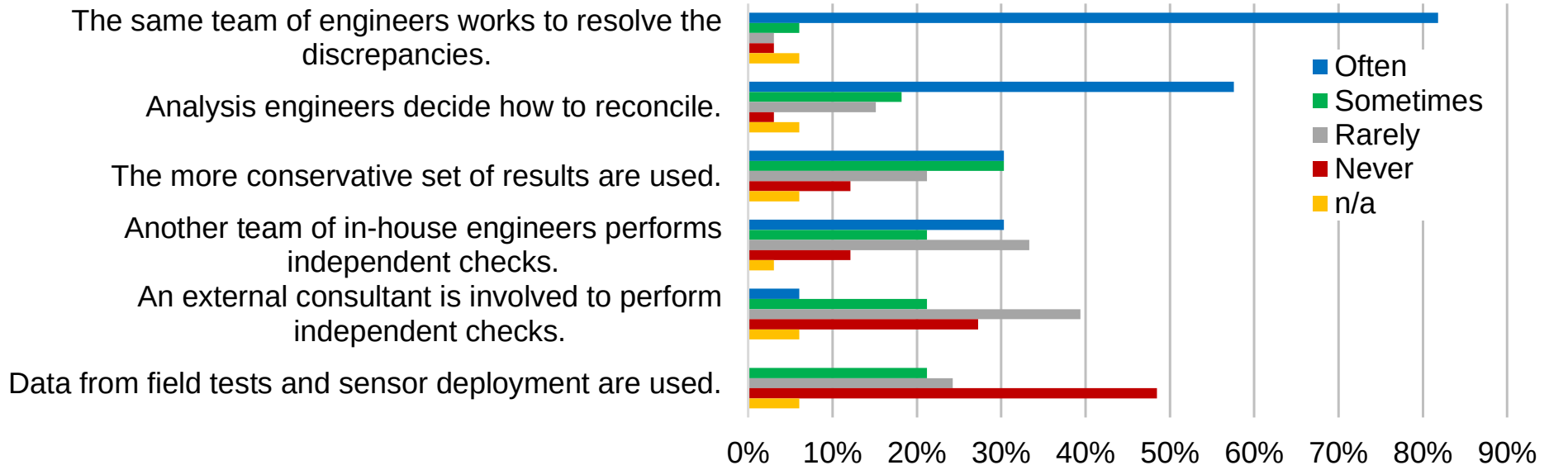

**Percentage of DOTs (N=51)**




**Percentence of** Responses from DOTs with written processes for verifying the in-house analysis results **(n=13)**

# 3) Quality Processes for In-House Projects

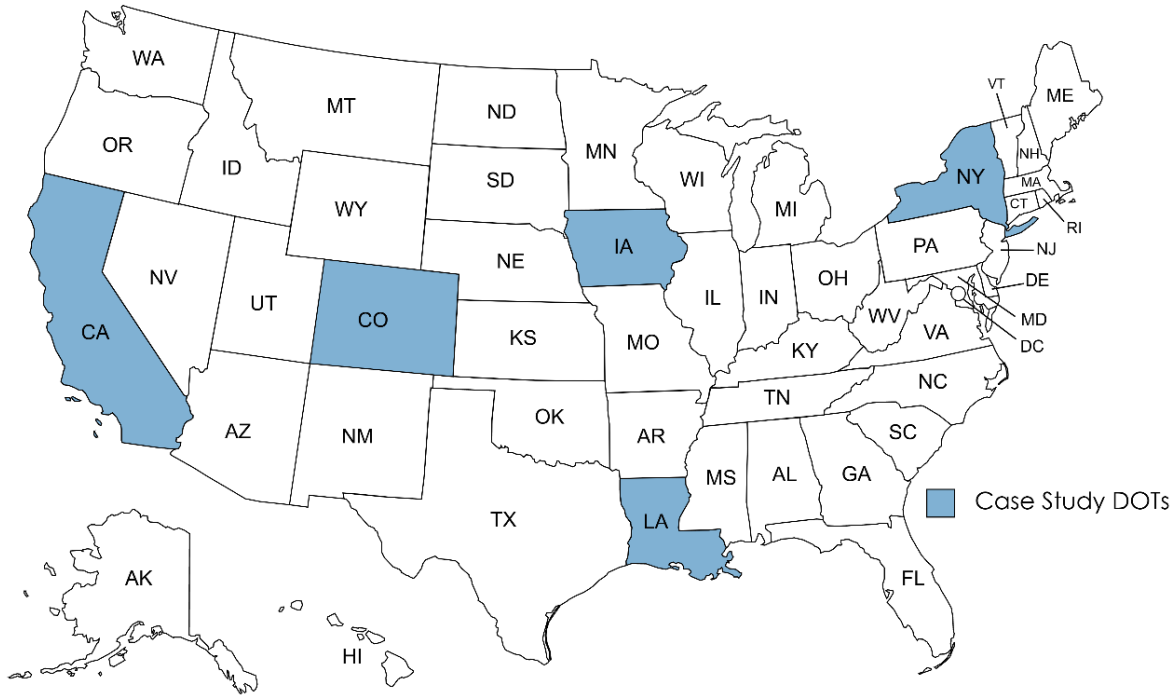



**Percentence of Responses** from DOTs with written processes for reconciling discrepancies between independent models **(n=8)**

# Case Examples

- Selection Criteria for Case Examples
  - Number of 'written process' responses to the survey,
  - Documents uploaded for 'written processes' while completing the survey,
  - Geographical location for selecting one DOT from each region, and
  - Willingness to participate in a follow-up interview (last question of the survey).



# Case Examples

- use two types of consultant selection processes:
  - project-specific and/or
  - statewide on-call.
- require consultants to either submit their QA/QC plans or follow the agency's specific QA/QC plans.
- most frequently use *'one-dimensional line girder analysis.'*
- require a checker to independently verify the accuracy of design engineer's models, calculations, and results.
- Caltrans established the *SASA branch* (only focused on structural modeling/analysis) while NYSDOT established the *Main Office Structures group* with 65 design staff (only performs analysis/final design).
- For training engineering staff, Caltrans established 6-week *'bridge design academy'* while NYSDOT has a 24-session *'Bridge 101'* training series.

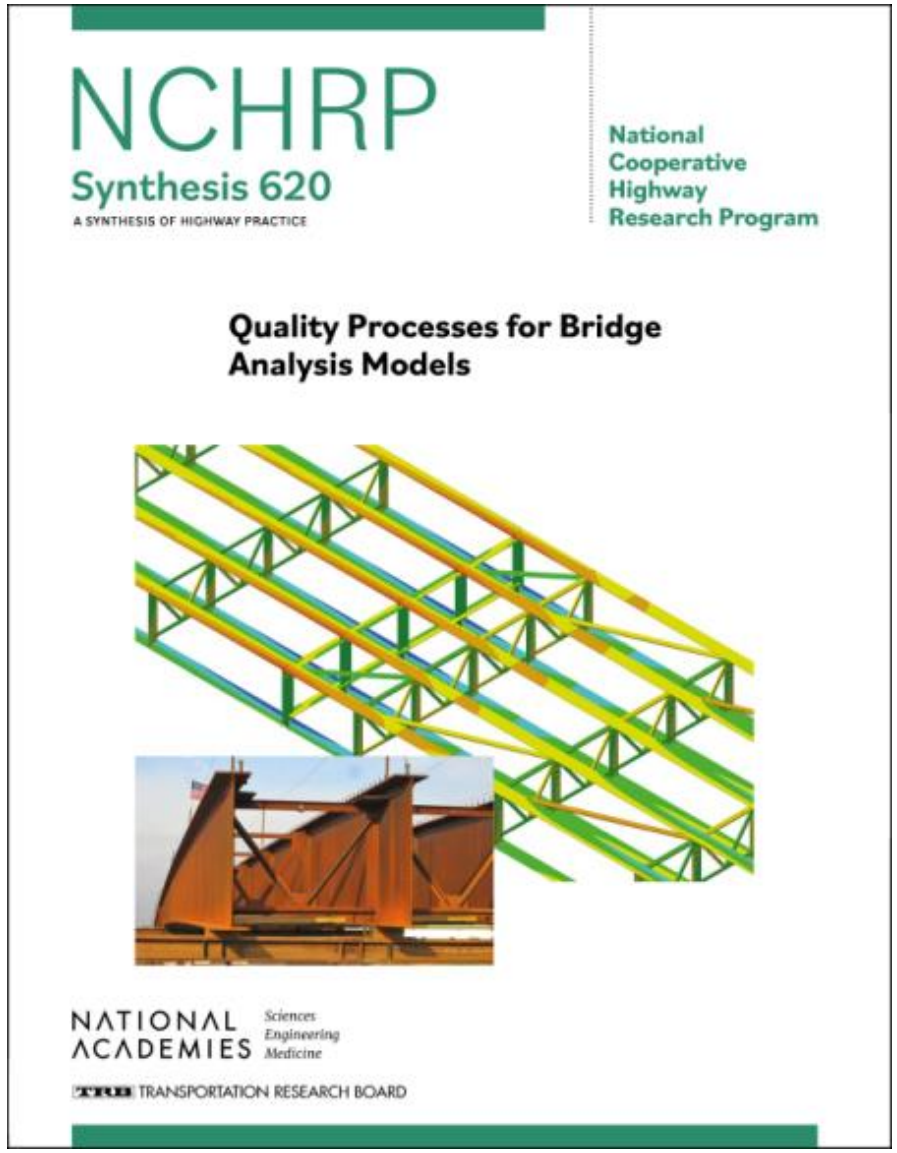
# Major Findings

- DOTs assign **59%** of their new bridge and bridge replacement designs to consultants while they assign **47%** of their existing bridge analyses to consultants.
- For three questions on the presence of consultant processes, **33%** of DOTs have ***'no written process'*** while only 16% have 'written processes' for all three activities asked.
- For 6 questions on the presence of in-house processes, **45%** have ***'no written process'*** while not a single DOT has written processes for all six activities asked.
- The most frequently used analysis method is the **'one-dimensional line girder analysis'** while the least frequently used method is the 'nonlinear finite element method'.

# Opportunities for Future Research

- Develop guidance on **what constitutes an effective QA/QC process** for the structural analysis models of bridges.
- Develop **bridge specific guidance** on the development and verification of the **finite element** and **strut-and-tie models**.
- Develop a **nationwide repository** for sharing analysis models between DOTs.
- Develop a **qualified training system** with standardized requirements for bridge engineers performing modeling of bridges.
- Developed **new training courses and seminars** to cast light on commonly misunderstood concepts such as verification, validation, uncertainty, error, and calibration.

# Related Publication (Open Access)

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## Quality Processes for Bridge Analysis Models

(2024)

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The design of bridges often involves the use of structural analysis models of varying degrees of complexity. A variety of analysis methods and software can be used to create and analyze these models, and the process can be quite complex, with significant amounts of input and output data. Quality assurance and quality control are two essential processes.

[read full description]

**Contributor(s):** National Academies of Sciences, Engineering, and Medicine; Transportation Research Board; National Cooperative Highway Research Program; Serhan Guner

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Dr. Serhan Guner, *Associate Professor*

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# THANK YOU!

## Questions?

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