United States Government Accountability Office

February 2021

TECHNOLOGY ASSESSMENT DESIGN HANDBOOK

Handbook for Key Steps and Considerations in the Design of Technology Assessments

Accessible Version

GAO-21-347G

Contents

Letter 1

Preface 1

Chapter 1: The Importance of Technology Assessment Design 8

1.1 The Purpose of Technology Assessment 8
1.2 Importance of Spending Time on Design 9

Chapter 2: Technology Assessment Scope and Design 11

2.1 Sound Technology Assessment Design 11
2.2 Stages and Considerations for Technology Assessment Design 12
2.2.1 GAO Technology Assessment Design Examples 20

Chapter 3: Approaches to Select Technology Assessment Design and Implementation Challenges 24

3.1 Ensuring the Design and Implementation of Technology Assessments Result in Useful Products for Congress and Other Policymakers 25
3.2 Determining the Policy Objective and Measuring Potential Effects 26
3.3 Researching and Communicating Complicated Issues 27
3.4 Engaging Relevant Stakeholders 28

Appendix I: Objectives, Scope, and Methodology 29

Appendix II: GAO's Expertise with Technology Assessments 45

Appendix III: Summary of Steps for GAO's General Engagement Process 48

Appendix IV: Example Methods for Technology Assessment 52

Appendix V: Overview of Scope and Design of Policy Options for Technology Assessments 59

Appendix VI: GAO Contact and Staff Acknowledgments 64

GAO contact 64
Staff Acknowledgments 64

Tables

Table 1: Summary of GAO's Technology Assessment Process 3
Text of Figure 1: Summary of Key Stages and Considerations of Technology Assessment Design 14

Table 2: Examples for Technology Assessment Objectives that Describe Status and Challenges to Development of a Technology 21
Table 3: Examples for Technology Assessment Objectives that Assess Opportunities and Challenges that May Result from the Use of a Technology 22
Table 4: Examples for Technology Assessment Objectives that Assess Policy Implications or Options Related to a Technology 23
Table 5: Challenges to Ensuring the Design and Implementation of Technology Assessments Result in Useful Products for Congress and Other Policymakers 25
Table 6: Challenges to Determining the Policy Objective and Measuring Potential Effects 26
Table 7: Challenges to Researching and Communicating Complicated Issues 27
Table 8: Challenges to Engaging Relevant Stakeholders 28
Table 9: Select Examples of Methodologies for Testimonial Evidence 53
Table 10: Select Examples of Methodologies for Documentary Evidence 55
Table 11: Select Examples of Methodologies for Physical Evidence 56

Figures

Figure 1: Summary of Key Stages and Considerations of Technology Assessment Design 12
Figure 2: Summary of Key Stages for Design of Policy Options for Technology Assessments 60
Text of Figure 2: Summary of Key Stages for Design of Policy Options for Technology Assessments 60

Abbreviations

AI	artificial intelligence
CRS	Congressional Research Service
EMS	Engagement Management System
OTA	Office of Technology Assessment
S&T	science and technology
STAA	Science, Technology Assessment, and Analytics
TA	technology assessment
TRL	technology readiness level

This is a work of the U.S. government and is not subject to copyright protection in the United States. The published product may be reproduced and distributed in its entirety without further permission from GAO. However, because this work may contain copyrighted images or other material, permission from the copyright holder may be necessary if you wish to reproduce this material separately.

441 G St. N.W.
Washington, DC 20548

Preface

The Government Accountability Office (GAO) provides Congress, federal agencies, and the public with non-partisan, objective, reliable information to help the government save money and work more efficiently and effectively. Science and technology (S&T) issues figure prominently in problems that Congress confronts, and one component of the assistance GAO provides to Congress is the production of technology assessments (TA). GAO TAs analyze recent S&T developments, highlight potential effects of technological change, and strive to make S&T concepts readily accessible to policymakers.

The Technology Assessment Act of 1972 (Public Law 92-484) established the Office of Technology Assessment (OTA) as an analytical support agency of the Congress. OTA was defunded in 1995.[1] In 2002, GAO began conducting TAs,[2] and in 2008, established a permanent TA function.[3] In 2019, GAO created the Science, Technology Assessment, and Analytics (STAA) team by pulling together and building upon existing elements and expertise within GAO.[4] For more details on GAO's expertise with technology assessments, see Appendix II.

The TA Design Handbook provides GAO staff and others with tools to consider for supporting robust and rigorous TAs, while following internal GAO guidance.[5] This handbook is particularly important given the need for GAO to provide insight and foresight on the effects of technologies and corresponding policy implications related to a wide range of S&T issues. Other organizations may also find portions of this handbook useful

[1]See Legislative Branch Appropriations Act, 1996, Pub. L. No. 104-53, 109 Stat. 514, 526 (1995).

[2]See H.R. Rep. No. 107-259, at 47 (2002) (Conf. Rep.) (directing the Comptroller General to obligate funds for a pilot program in technology assessment).

[3]See Consolidated Appropriations Act, 2008, Pub. L. No. 110-161, 112 Stat. 1844, 2249 (2007) (providing up to $2.5 million of amounts appropriated to GAO for technology assessment studies).

[4]See H.R. Rep. No. 115-929, at 213 (2018) (Conf. Rep.) (encouraging GAO to reorganize its technology and science function by creating a new, more prominent office within GAO).

[5]Some of these tools may be useful to teams that design other types of engagements.

as they consider or conduct TAs, although their needs, approaches, and relationships with stakeholders and government bodies may differ.

Technology Assessments

New technologies can have a range of effects, potentially both positive and disruptive, that TAs can explore.[6] GAO has broadly defined TA as the thorough and balanced analysis of significant primary, secondary, indirect, and delayed interactions of a technological innovation with society, the environment, and the economy and the present and foreseen consequences and effects of those interactions.[7] GAO TAs share some

History of Science and Technology Work at GAO

The Government Accountability Office (GAO) has conducted science and technology (S&T) work for close to 50 years, including technology assessments for almost two decades. In 2018, Congress encouraged GAO to form an S&T-focused team, recognizing that the scope of technological complexities continue to grow significantly and there is need to bolster capacity of, and enhance access to, quality, independent science and technological expertise for Congress. On January 29, 2019, GAO formally created the Science, Technology Assessment, and Analytics (STAA) team by pulling together and building upon existing elements within GAO. Since then, STAA has provided over 50 products to Congress, including technology assessments covering a wide range of science, technology, and information technology issues. In addition, STAA has also worked collaboratively with other teams at GAO on about 275 products since its creation.

Source: GAO-20-246G and review of GAO product line data. | GAO-21-347G

[6]In this context, GAO refers to technology broadly as the practical application of knowledge in a particular area, and the resulting capability given by that application. Technology may also refer to a manner of accomplishing a task using technical processes, methods, or knowledge as well as the specialized aspects of a particular field of endeavor.

[7]There is no single agreed-upon typology/taxonomy of or approach to TAs. Examples of different TA approaches found in the literature include, but are not limited to: strategic, early-warning, future-oriented, classical or expert, real-time, constructive, and participatory. For example, expert TAs may emphasize expert knowledge, and participatory TAs may emphasize stakeholder and public involvement. Please refer to Appendix IV for further discussion of example methodologies that can be used with these approaches.

common design principles with GAO's general audit engagement process, which is centered on intentional and purpose-driven design.[8]

While general design principles are shared across GAO's product lines, TAs are distinct from other GAO products due to their specialized content, scope, and purpose, which warrant different considerations.[9] Table 1 highlights some similarities and differences between TAs and other GAO product lines, including where TAs follow aspects of GAO's general audit engagement process, and where TAs may further emphasize certain steps or require additional steps during the engagement process.[10]

Table 1: Summary of GAO's Technology Assessment Process

Steps in plain text are process steps for both general audit and TA products. Steps in bold italics are either additional process steps or a particular emphasis for technology assessments (TA).[a]

Phase	Steps
Initiation	• Discussion with congressional requesters, if applicable, regarding scope and focus of the engagement[b] • ***Consideration of technology state, relevant stakeholder expertise, and potential policy implications*** • ***Consideration of whether policy options may be appropriate for inclusion***
Design	• Performance of initial research • Consideration of relevant sections of GAO's quality standards and GAO methodological and technical standards and guides • Consultation with GAO subject matter experts and internal stakeholders, as needed • Discussion with agency officials and experts • ***Identification of and consultation with external experts, such as science, policy, and industry experts, who may also serve as external reviewers***[c] • ***Identification of possible policy options, if appropriate***

[8]For example, both TAs and GAO's general audit engagement process includes a robust initiation and design process that considers factors such as: requester's interests and stakeholder input, the current state of knowledge, and relevant and appropriate methodological considerations in defining and investigating appropriate research questions. Also part of GAO's general audit engagement process is internal message development and agreement, along with external review. Design decisions are implemented and revisited throughout the audit engagement process. Refer to Appendix III for a summary of the typical GAO engagement process, of which design is a part.

[9]Examples of other GAO products include performance audits, financial audits, and other routine non-audit products.

[10]Other product lines may emphasize these elements as well, depending on engagement needs.

Phase	Steps
Message development	• Collection and analysis of evidence • Assessment of evidence and research results • Development of draft findings • ***Ongoing engagement with external experts*** • ***Conduct and discuss policy options assessment, if appropriate***[d]
External review	• Request views from relevant third parties, if applicable, and request comments from relevant federal agencies, ***as appropriate*** • ***Request comments from external experts, and others as appropriate***

Source: GAO-20-246G and additional review of GAO product lines. | GAO-21-347G

[a]Not all steps have been included in this table.

[b]GAO performs work for Congress that is initiated through requests, legislation (i.e.., statutory mandates), and Comptroller General Authority (i.e., GAO-initiated work). In addition, GAO conducts work in response to requests for technical assistance (e.g., briefings on prior or ongoing work, responses to technical questions, short-term analysis of agency programs or activities, detailed follow-up, and hearing support).

[c]For example, GAO has contracted with the National Academies of Sciences, Engineering, and Medicine to help GAO identify experts on various scientific topics and leverage National Academies assistance to convene GAO expert meetings.

[d]Unlike GAO's general audit products, which often contain recommendations, TAs may include policy options designed to enhance benefits or mitigate challenges of a technology.

STAA has taken a number of steps to account for the unique nature of TAs and related S&T work. The effects of technological interactions can have implications, and recognizing this, GAO includes policy options in some of its products. Policy options are defined as a set of alternatives or menu of options that may enhance benefits or mitigate challenges of a technology, and which policymakers such as legislative bodies, government agencies, standards-setting organizations, industry, and other groups, could consider taking.[11] A first step for developing policy options is to define a policy objective, which guides the development of the options by stating the overall aim, and by helping to identify the landscape and scope of the options.[12] GAO is continuing to explore approaches to making policy options a standard feature in its S&T work

[11]Policy options are for policymakers to consider and take action on at their discretion. In addition, GAO TAs strive to list likely policy options supported by analysis, but the list may not be exhaustive, and policymakers may choose to consider other policy options not listed by GAO.

[12]TA teams may identify more than one policy objective if the technology's landscape and scope is particularly complex. Alternatively, if a team chooses not to include a policy objective as part of a TA's scope and design, the final product will not include policy options.

and has included them in four TAs to date.[13] GAO's experiences with those TAs inform this update to the handbook, and we have included considerations related to the development of policy options that teams may wish to consider at each phase of TA design.

Objectives, Scope, and Methodology

This handbook elaborates on GAO's approach to TA design. It outlines the importance of TA design (Chapter 1), describes the process of developing TA design (Chapter 2), and provides approaches to select TA design and implementation challenges (Chapter 3). The handbook generally follows the format of the 2012 GAO methodology transfer paper, *Designing Evaluations*.[14] This is an update to the handbook published in December 2019.[15] We are updating this handbook to include the experiences of GAO teams and relevant literature since the handbook was initially published as well as comments made by external experts and the public submitted between December 2019 and December 2020.

The following summarizes the approach we used to identify and document TA design steps and considerations for this handbook, and to update the handbook. For more information, please refer to Appendix I: Objectives, Scope, and Methodology.

- Reviewed select GAO documents, including *Designing Evaluations* (GAO-12-208G), published GAO TAs, select GAO products utilizing policy analysis approaches to present policy options, and other GAO reports
- Reviewed select Office of Technology Assessment reports
- Reviewed select Congressional Research Service reports

[13]GAO, *Artificial Intelligence in Health Care: Benefits and Challenges of Technologies to Augment Patient Care*, GAO-21-7SP (Washington, D.C.: Nov. 30, 2020); GAO, *5G Wireless: Capabilities and Challenges for an Evolving Network,* GAO-21-26SP (Washington, D.C.: Nov. 24, 2020); GAO, *Artificial Intelligence in Health Care: Benefits and Challenges of Machine Learning in Drug Development,* GAO-20-215SP (Washington, D.C.: Dec. 20, 2019); and GAO, *Irrigated Agriculture: Technologies, Practices, and Implications for Water Scarcity,* GAO-20-128SP (Washington, D.C.: Nov. 12, 2019).

[14]*Designing Evaluations* describes designs of program evaluations. See GAO, *Designing Evaluations: 2012 Revision*, GAO-12-208G (Washington, D.C.: Jan. 2012).

[15]GAO, *Technology Assessment Design Handbook*, GAO-20-246G (Washington, D.C.: Dec. 4, 2019).

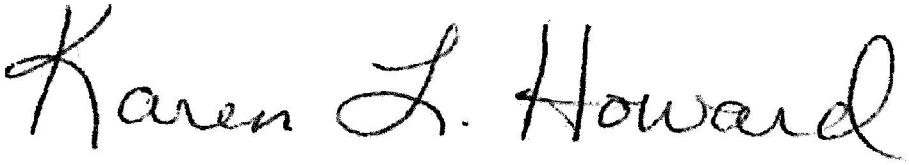
- Reviewed select English-language literature regarding TAs and related to development and analysis of policy options
- Consulted with external experts and performed outreach, including holding an expert meeting to gather input regarding TA design, soliciting comments from external experts who contributed to GAO TAs published since 2015, and soliciting comments from the public[16]
- Reviewed experiences of GAO teams that have successfully assessed and incorporated policy options into GAO products and TA design, including related to challenges to TA design and implementation and possible solutions

To update this handbook, we conducted our work from March 2020 to February 2021 in accordance with all sections of GAO's Quality Assurance Framework that are relevant to our objectives. The framework requires that we plan and perform the engagement to obtain sufficient and appropriate evidence to meet our stated objectives and to discuss any limitations in our work. We believe that the information and data obtained, and the analysis conducted, provide a reasonable basis for any findings and conclusions in this product.

[16]We solicited comments on this handbook from December 2019 to December 2020.

If you have any questions concerning this handbook, please contact Timothy M. Persons or Karen L. Howard at (202) 512-6888 or personst@gao.gov or howardk@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs can be found on the last page of this handbook. Key contributors to this handbook are listed in Appendix VI.

Timothy M. Persons, PhD
Managing Director
Science, Technology Assessment, and Analytics
Chief Scientist, GAO



Karen L. Howard, PhD
Director
Science, Technology Assessment, and Analytics

February 18, 2021

Chapter 1: The Importance of Technology Assessment Design

This chapter underscores the importance of TA design, outlining reasons for performing TAs and for spending time on their design. This chapter is based on reviewing the results of a literature search, an expert meeting, select GAO reports, the experiences of GAO teams, and public and external expert comments. For details, see Appendix I: Objectives, Scope, and Methodology.

1.1 The Purpose of Technology Assessment

TAs are significant given the growing effects of S&T on society, economy, and other areas. Technological change can be positive, but also disruptive, making it critical for Congress and other policymakers to understand and evaluate the effects of technology—for example, to ensure national security and global competitiveness are maintained.

GAO TAs are often requested by Members of Congress and congressional committees, who may use them to, among other things, make resource allocation decisions to address research gaps or to inform legislation or the development of a national strategy.[17]

TAs help Congress and other policymakers understand and evaluate the effects of technology by:

- Highlighting potential short, medium, and long-term effects of a technology
- Elaborating on and communicating the challenges and benefits associated with a technology, including early insights into the potential effects of a technology
- Highlighting the status, viability, relative maturity, and public and private uses of a technology

[17]GAO's congressional protocols expand on how GAO performs work pursuant to law or as directed by congressional committees. For more information, see *GAO's Congressional Protocols.* GAO-17-767G. Washington, D.C.: July 17, 2017. For examples of research questions and objectives from published GAO TAs, see tables 2-4.

- Supporting planning and evaluation of federal investments in S&T
- Describing the regulatory environment of a technology
- Exploring ethical, legal, and social questions that may arise from the application of a technology

Technologies present opportunities and challenges that may vary, depending in part on the policy context in which they are assessed. Therefore, part of a TA is considering the policy context surrounding a given technology. Recognizing this, GAO may, where appropriate, identify and analyze policy options as part of its TAs, along with other information and analyses, to clarify and summarize policy-related issues and challenges to support policymakers' decision-making. In this situation, policy options can be defined as a set of alternatives or menu of options that policymakers, such as legislative bodies, government agencies, standards-setting organizations, industry, and other groups, could consider taking.[18] Policy options can be used to articulate a range of possible actions a policymaker could consider that may enhance benefits or mitigate the challenges of a technology, in the context of a given policy objective. Policy options in TAs are addressed to policymakers broadly, not to a specific agency or entity, and do not endorse a particular course of action. They are not recommendations or matters for congressional consideration, which GAO traditionally makes in other product lines.[19]

1.2 Importance of Spending Time on Design

As part of the TA process, developing a written TA design, including a written work plan, helps teams agree on and communicate a clear plan of action to the team's advisers, requesters, and other stakeholders.[20] Written TA designs also help guide and coordinate the project team's activities and facilitate documentation of decisions and procedures in the

[18]As stated previously, policy options are for policymakers to consider and take action on at their discretion. In addition, GAO TAs strive to list likely policy options supported by analysis, but the list may not be exhaustive, and policymakers may choose to consider other policy options not listed by GAO.

[19]Although policy options in GAO TAs do not endorse a particular course of action, GAO's analysis of multiple feasible alternatives is intended to demonstrate that various policy options have trade-offs, with each potentially fulfilling certain goals more than others. This information could help policymakers choose options based on these trade-offs and which goals they hope to achieve.

[20]For example, see Appendix III for additional information on the design and project plan templates that GAO uses as part of its quality standards. GAO TAs use these templates.

final product. In addition, focusing the TA on answering specific researchable questions can assist teams to define and select the appropriate scope and approach, ensuring usefulness of the product to the intended users. More specific reasons for spending time on systematically designing a TA include:

- Enhance its quality, credibility, and usefulness
- Ensure independence of the analysis
- Ensure effective use of resources, including time

Data collection and quality assurance of data can be costly and time-consuming. A thorough consideration of design options can ensure that collection and analysis of the data are relevant, sufficient, and appropriate to answer the researchable question(s), and helps to mitigate the risk of collecting unnecessary evidence and incurring additional costs.

Chapter 2: Technology Assessment Scope and Design

This chapter highlights design stages, cross-cutting considerations, and GAO examples for sound TA design. To ensure that the information and analyses in TAs meet policymakers' needs, it is particularly useful to outline the stages and considerations involved in sound TA design, while remaining aware of the iterative and nonlinear process of designing a TA. The information presented in this chapter is based on reviewing the results of a literature search, an expert meeting, select GAO reports, experiences of GAO teams, and public and external expert comments. For details, see Appendix I: Objectives, Scope, and Methodology.

2.1 Sound Technology Assessment Design

Below are questions to consider for a sound TA design. Reflecting on these questions may help teams make important decisions (like selecting an appropriate design), weigh various factors, and ensure quality TAs.

- Does the design address congressional and other policymakers' needs?
- Will the design yield a quality, independent, balanced, thorough, and objective product?[21]
- Will the design likely yield information that will be useful to stakeholders?
- Will the design likely yield valid conclusions on the basis of sufficient and credible evidence?
- Will the design yield results in the desired time frame?
- Will the design likely yield results within the constraints of the resources available?
- How will policy options be identified and assessed, if applicable?

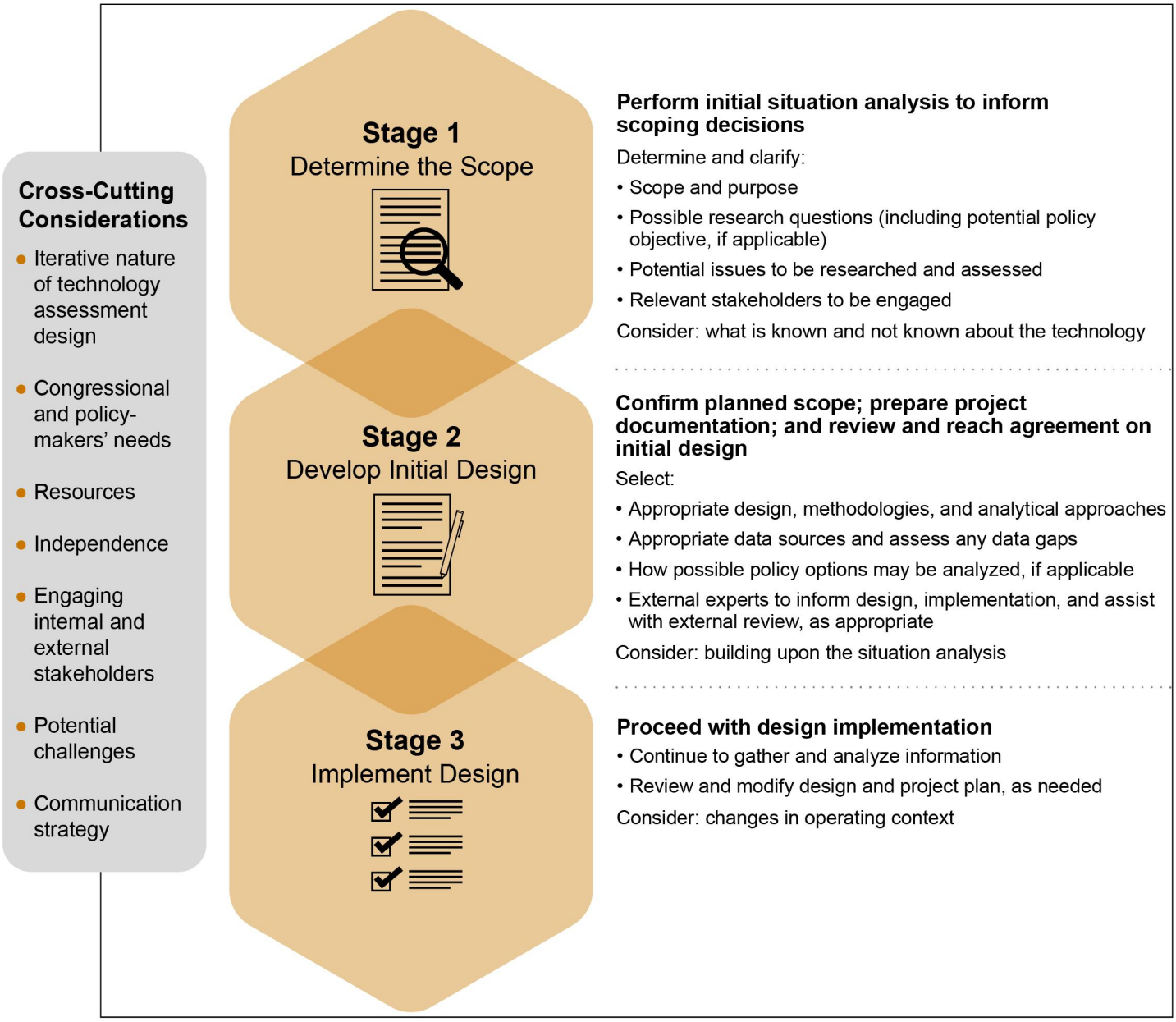
[21]TA teams can use their organization's existing protocols and policies to ensure independence of analysis.

2.2 Stages and Considerations for Technology Assessment Design

Figure 1 outlines three stages of TA design, and the subsequent sidebar elaborates on seven considerations. While Figure 1 presents TA design as a series of stages, actual execution is highly iterative and nonlinear. As with all GAO engagements, teams need to be prepared to re-visit design decisions as circumstances change.[22] In addition, TAs must meet GAO's rigorous quality standards, which are designed to ensure that all GAO products provide accurate, credible, and balanced information. GAO's quality standards and standards of evidence apply to all GAO products, including TAs.

Figure 1: Summary of Key Stages and Considerations of Technology Assessment Design

[22]Refer to Appendix III for a summary of the typical GAO engagement process, of which design is a part.



Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

Text of Figure 1: Summary of Key Stages and Considerations of Technology Assessment Design

Cross-Cutting Considerations

- **Iterative** nature of technology assessment design
- Congressional and policymakers' needs
- Resources
- Independence
- Engaging internal and external stakeholders
- Potential challenges
- Communication strategy

Stage 1: Determine the Scope

Perform initial situation analysis to inform scoping decisions
Determine and clarify:

- Scope and purpose
- Possible research questions (including potential policy objective, if applicable)
- Potential issues to be researched and assessed
- Relevant stakeholders to be engaged
- Consider: what is known and not known about the technology

Stage 2: Develop Initial Design

Confirm planned scope; prepare project documentation; and review and reach agreement on initial design
Select:

- Appropriate design, methodologies, and analytical approaches
- Appropriate data sources and assess any data gaps
- How possible policy options may be analyzed, if applicable
- External experts to inform design, implementation, and assist with external review, as appropriate
- Consider: building upon the situation analysis

Stage 3: Implement Design

Proceed with design implementation

- Continue to gather and analyze information
- Review and modify design and project plan, as needed
- Consider: changes in operating context

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

Cross-Cutting Considerations

Below are some considerations for the team to think about while designing a technology assessment (TA) and throughout the process of performing the TA. This list is not exhaustive, and some of the considerations may not be unique to TAs.

The iterative nature of TA design: As circumstances change and new information comes to light, it may be necessary to revisit scope and design.

Congressional and policymakers' needs: Assess needs and interests of congressional requester(s) and other potential policymakers, as applicable.

Resources: These include staff availability, staff expertise, and time available. Trade-offs may need to be considered, such as between resources and potential scope.

Independence: This includes potential or perceived threats to independence, including conflicts of interest, bias, and implicit bias.

Engaging internal and external stakeholders: Consider and consult with relevant internal and external stakeholders as early as possible and during all design stages.

Potential challenges: Consider potential challenges to design and implementation of the TA, such as: (1) possible changes in operating environment; (2) characterizing or quantifying anticipatory factors, uncertainty, and future condition(s); and (3) lack of or limitations with data. See Chapter 3 for more specific examples.

Communication strategy: Consider potential users of the product(s) and how information regarding the TA will be communicated. How results are communicated can affect how they are used, so it is important for TA teams to discuss communication options.

Source: GAO-20-246G. | GAO-21-347G

Stage 1: Determine the Scope

During this stage, TA teams will make scoping decisions. Scoping decisions are informed by an initial situation analysis that may be used to:[23]

- Develop an initial understanding of the technology (such as the state of the technology) and context of the technology (such as social, political, legal, and economic factors)
- Identify internal and external stakeholders[24]
- Identify other preliminary activities (such as initial interviews and identifying potential data sources)
- Inform the purpose of the work and possible objectives (also known as research questions), including the policy objective, if applicable
- Identify potential issues to be researched and assessed

[23]An initial situation analysis may entail a preliminary literature search, early interviews with experts, and review of relevant GAO bodies of work, among other methods. See Appendix IV for additional information regarding methods.

[24]Stakeholders are described later in this section, and include a wide range of internal and external stakeholders who advise, review, contribute to, and may be affected by the work, including the possible policy objective and subsequent policy options.

Defining Scope

To make scoping decisions teams may find it useful to define and delineate scope according to, for example:

- Type, part, or level of maturity of the technology
- Timeframe, economic sector(s), or geography
- Types of effects and outcomes
- Institutional considerations, such as previous work by GAO and other organizations
- Availability of information, including possible proprietary nature of information
- Degree of knowledge, lack of information, or prevalence of conflicting information related to the technology
- Extent to which the approach will assess the technology

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

TA teams may identify a possible policy objective, as applicable, based on the congressional request, evidence, and other factors. Teams will need to ensure that the policy objective is balanced by not generating a bias for a single potential course of action.[25] The policy objective serves to guide the development of policy options by stating their overall aims, and helping to identify the landscape and scope of policy options.

During this stage, and as early as possible, teams identify and may start engaging with relevant internal and external stakeholders, including those related to the potential policy objective. Such stakeholders could include:

- Internal stakeholders, such as: individuals or units with relevant subject matter, technical, methods, or other types of expertise[26]
- External stakeholders, such as: federal agencies, academic researchers, industry or nonprofit groups, and others who have knowledge or interest in the specific topic, and may be affected by the implications of the technology[27]

Scoping decisions may ultimately affect the conclusions a TA can draw, as well as the policy objective and options teams can consider. Therefore, teams should document areas that have been scoped out, along with any other key decisions, limitations, and considerations that provide context to the conclusions.

[25]For example, the policy objective in GAO's most recent TA on artificial intelligence in health care stated: What policy options could help maximize benefits and mitigate challenges surrounding the use of AI tools to augment patient care? Alternatively, GAO's 5G wireless TA formulated policy options around the policy objective of achieving expected capabilities and uses of 5G networks in the United States. See GAO-21-7SP and GAO-21-26SP for more information.

[26]For example: mission teams may have performed work in the related area(s), and have subject matter and agency-related knowledge and expertise; the Office of General Counsel may provide insight regarding questions relating to ethical, legal, or regulatory context of the technology; communications analysts can support product development; and other internal experts, such as biologists, chemists, physicists, engineers, statisticians, information technology specialists, economists, social scientists, and data scientists also can provide valuable context and information.

[27]This includes relevant stakeholders for each policy option, some of whom may or may not benefit from a policy option.

Stage 2: Develop Initial Design

During this phase, TA teams continue to build on the situation analysis work and gather more background information.

In addition, TA teams:

- Confirm the scope from stage 1
- Prepare project documentation
- Reach agreement with stakeholders on the initial design
- Further highlight limitations, assumptions, divergent points of view, potential bias, and other factors that may help the team select a design
- Refine the objectives (research questions), including the policy objective, as applicable
- Identify and select appropriate design, methodologies, and analytical approaches (refer to the next section of this chapter for example TA design approaches and Appendix IV for examples of methods)
- Identify and select appropriate data sources, assess any data gaps, and assess the need to gather data
- Identify, select, and possibly develop appropriate dimensions of analysis, if applicable
- Identify the possible policy options that will be considered and describe how they may be analyzed, if applicable
- Identify and consult with stakeholders, such as external experts, to inform design and implementation and assist with external review, as appropriate[28]

Examples from GAO Technology Assessments

Examples of data collection and analytical techniques used in GAO technology assessments (TA) to date include: interviews, literature reviews, expert meetings, Delphi method, site visits, technology readiness assessments, surveys, conceptual models, small group discussion, and content analysis, among others. The Office of Technology Assessment (OTA) reported using similar methodologies for its TAs (OTA, *Policy Analysis at OTA: A Staff Assessment*, 1983).

Source: GAO-20-246G. | GAO-21-347G

The development of policy options is very context- and TA-specific. TA teams may develop a list of possible policy options based on an initial literature search, initial discussion with experts, and other factors.[29] TA

[28]External review, also called “peer review,” may include review of draft products by external subject matter experts that TA teams may have engaged with during earlier design stages. The external review process can help ensure that the information presented in TAs is accurate, balanced, and of high quality.

[29]These possible policy options may evolve over time as teams collect more evidence and perform further analysis.

teams may also find it necessary at this stage to initially group policy options, such as by similar themes, or eliminate some options as being beyond the scope of the TA.[30] TA teams will need to think about whether the possible policy options are appropriate to the size and scope of the TA, as well as whether they are in line with the policy objective and the overall TA purpose. In keeping with the iterative nature of TA design and execution, any policy option list will be revisited, modified, or refined, as needed, as the work progresses and more information is gained. TA teams may also need to plan to include policy analysis and exploration of the potential effects of each policy option during subsequent design and implementation stages.

Furthermore, if policy options are being considered, it is important to determine the relevant dimensions along which to analyze the options. The dimensions will be highly context-specific, vary from TA to TA, and depend on the scope and policy objective of the TA. Dimensions for analyzing policy options and assessing the evidence may include: relevance to the policy objective, stakeholder impacts, cost/feasibility, legal implications, magnitude of impact, ease of implementation, time frames, degree of uncertainty, and potential for unintended consequences. Appendix V provides an overview of scope and design considerations specific to policy options for TAs.

Stage 3: Implement Design

During this stage, the design and project plan is being implemented, potentially while aspects of stage 2 are still underway. It is important to consider changes in the operating context—such as changes in the operating environment, understanding of the issues, and access to information—and review and make changes to the design and project plan accordingly.

If a policy options list was developed earlier in design, it may be necessary to revisit the list as work progresses. During this stage, TA teams may gather additional information regarding the policy options, further analyze policy options, and present the results of the analysis. Teams should present policy options in a balanced way, including

Examples from Other GAO Products

We reviewed select GAO products that used policy analysis to present policy options. We found that these products used a variety of data collection and analytical approaches, such as: interviews, literature review, survey, expert meetings, site visits, case studies, analysis of secondary data, content analysis, among others.

Source: GAO-20-246G. | GAO-21-347G

[30]Themes for grouping of policy options may include: subject matter, type of policy, or phase of technology.

presentation of opportunities and considerations, and not resulting in a single overall ranking of policy options.

2.2.1 GAO Technology Assessment Design Examples

We found that GAO TAs used a variety of design approaches and methodologies to answer various categories of design objectives (researchable questions). GAO TAs generally include one or more of the following categories of design objectives, which are not mutually exclusive: (1) describe status of and challenges to development of a technology; (2) assess opportunities and challenges arising from the use of a technology; and (3) assess policy implications or policy options related to a technology. Provided below are example questions, design approaches, and GAO TAs, for each of these categories of objectives. GAO TA examples were used given our familiarity with GAO products, though numerous non-GAO TA design examples exist. This is not intended to be a comprehensive list of design examples. For more examples of methodologies, please refer to Appendix IV.

Describing the status and challenges to the development of a technology. Table 2 provides example questions, design approaches, and GAO TAs for design objectives related to describing the status and challenges to the development of a technology. Questions may address, for example, what the current state of the technology is, and may involve identifying and describing the status of the technology, which GAO TAs have done using a variety of methods.

Table 2: Examples for Technology Assessment Objectives that Describe Status and Challenges to Development of a Technology

Example questions	Example design approaches	Examples from GAO technology assessments (TA)
• What is current state of the technology? • What are alternative applications of the technology? • Does the status of technology vary across different applications or sectors where technology is being developed?	• Identify and describe status of select applications of the technology • Assess technical capabilities of select applications or sectors where technology is being developed	• A TA team reported on current state, examples, and technical status of different applications of climate engineering technologies, based on: review of literature; interviews with scientists, engineers, government officials, and other relevant stakeholders; a public opinion survey; an expert meeting; and assignment of technology readiness levels (TRLs)[a] (GAO-11-71) • To examine collection methods and limitations of COVID-19 surveillance data and approaches and limitations to analyzing these data, a TA team obtained and reviewed relevant literature and data, including technical data on specific models (GAO-20-635SP)
• What are technical challenges to the development of the technology?	• Review and observe applications of technology • Gather and analyze reports or other evidence of technical challenges to development of technology	• To identify and consider technical challenges associated with technologies to enable rapid diagnoses of infectious diseases, a GAO team reviewed select agency documentation and scientific literature; interviewed agency officials, developers, and users of these technologies; conducted site visits to select developers; and convened an expert meeting to provide technical assistance and review the GAO draft report (GAO-17-347)
• What technologies are available or under development that could be used to address a specific problem or issue? • What challenges do these technologies face?	• Gather and analyze documentary and testimonial evidence of technologies in use or that could be put to use to address problem of interest • Identify challenges and potential approaches addressing both the problem of interest and challenges in developing technology	• A TA team identified technologies that could mitigate the effects of large-scale electromagnetic events, along with issues and challenges associated with development of these technologies by reviewing and synthesizing technical reports and interviewing federal agency officials (GAO-19-98)

Source: GAO-20-246G and review of GAO technology assessments. | GAO-21-347G

[a]TRLs provide a standard tool for assessing the readiness of emerging technologies. The team adopted an existing categorization of technologies aimed generally at either carbon dioxide removal or solar radiation management. The team then rated and compared TRL levels of select technologies within these categories.

Assessing opportunities and challenges that may result from the use of a technology. Table 3 provides example questions, design approaches, and GAO TAs for design objectives related to assessing opportunities and challenges that may result from the use of a technology. Questions may address, for example, what are the expected or realized benefits of the technology, and may involve gathering and assessing evidence on the results from using the technology, which GAO TAs have done using a variety of methods.

Table 3: Examples for Technology Assessment Objectives that Assess Opportunities and Challenges that May Result from the Use of a Technology

Example questions	Example design approaches	Examples from GAO technology assessments (TA)
• What are the expected or realized benefits of the technology? • What unintended consequences may arise from using the technology?	• Gather and assess existing reports or other evidence on results from using technology • Partner with an external organization to reinforce or complement the diverse and interdisciplinary nature of TAs	• A TA team determined expected and realized benefits and unintended consequences from use of artificial intelligence in select areas by: reviewing relevant literature; interviewing select experts, developers, and other stakeholders (including to inform a pre-meeting reading package); convening an expert meeting; and seeking review of the draft report from members of the expert meeting and two additional experts (GAO-18-142SP) • TA teams collaborated with the National Academy of Medicine to assess the implications of the use of artificial intelligence/machine learning in drug development (GAO-20-215SP) and to improve patient care (GAO-21-7SP)
• Do uses or outcomes of the technology differ across geographic, economic or other social groups or sectors?	• Gather and analyze information to assess potential differences in use or impacts (e.g. to employment, health, or the environment) across different economic or other social sectors or groups, either quantitative or qualitative, depending upon available information	• To assess differences in use and impacts of sustainable chemistry technologies across different sectors, a TA team reviewed key reports and scientific literature; convened a group of experts; interviewed representatives of state and federal agencies, chemical companies, industry and professional organizations, academic institutions, nongovernmental organizations, and other stakeholders; conducted site visits to federal laboratories; attended two technical conferences; and conducted a survey of selected chemical companies (GAO-18-307)

Source: GAO-20-246G and review of GAO technology assessments. | GAO-21-347G

Assessing policy implications or policy options related to a technology. Table 4 provides example questions, design approaches, and GAO TAs, for design objectives related to assessing policy implications or policy options related to the use of a technology. Questions may address, for example, what are the costs and benefits of a technology, which GAO TAs have done using a variety of methods.

Table 4: Examples for Technology Assessment Objectives that Assess Policy Implications or Options Related to a Technology

Example questions	Example design approaches	Examples from GAO technology assessments (TA)
• What are the costs and benefits of specified technologies?	• Gather and analyze information on the costs, benefits, and risks associated with the implementation of alternative technologies or systems involving specific technologies • Compare cost-effectiveness of alternative technologies or systems	• A TA team developed four scenarios for using biometric technologies in border security by reviewing relevant statutes and regulations; interviewing government officials; reviewing test documentation from academic, government, and industry sources; and analyzing Immigration and Naturalization Service statistics, among other things. For each scenario, the team analyzed select costs, benefits, and risks associated with implementation (GAO-03-174)
• What are policy implications resulting from advances in the technology?	• Gather and analyze reports, test results, developer and stakeholder perspectives, and other relevant information on the legal, social, economic, equity or other relevant implications resulting from advances in the technology	• To examine policy issues and potential effects of several policy options for federal government use of cybersecurity for critical infrastructure protection, a TA team analyzed federal statutes and regulations that govern the protection of computer systems; reviewed relevant literature; conducted interviews; convened a group of experts; and obtained comments on the draft report from the Department of Homeland Security and the National Science Foundation (GAO-04-321)
• What policy options could address challenges related to a technology to achieve a specified outcome?	• Gather and analyze reports, test results, stakeholder perceptions or other relevant information to identify and synthesize policy options • Analyze policy options on dimensions such as cost-effectiveness or ease of implementation • Use quantitative and qualitative approaches to analyze and display relevant information	• To identify and analyze policy options that federal policymakers could consider to reduce the impact of irrigated agriculture in areas facing water scarcity in the United States, a TA team reviewed scientific literature; convened an expert meeting; interviewed farmers, academics, industry representatives, and federal officials; modeled water use in an illustrative watershed; and performed regression analysis on U.S. Department of Agriculture irrigation, crop, and technology data (GAO-20-128SP) • To formulate policy options to achieve expected capabilities and uses of 5G networks in the United States, a TA team interviewed government officials, industry representatives, and researchers; reviewed technical literature; held an expert meeting; and analyzed responses to a questionnaire sent to 146 stakeholders. (GAO-21-26SP)

Source: GAO-20-246G and review of GAO technology assessments. | GAO-21-347G

Chapter 3: Approaches to Select Technology Assessment Design and Implementation Challenges

This chapter describes select challenges regarding TA design and implementation, as well as possible strategies to mitigate those challenges. The information in this chapter is based on reviewing the results of a literature search, an expert meeting, select GAO reports, experiences of GAO teams, and public and external expert comments. The tables provided below are not intended to be a comprehensive list of challenges or strategies. For details, see Appendix I: Objectives, Scope, and Methodology.

During our review, we identified a variety of design and implementation challenges teams face that may impede their ability to clearly present objective and balanced information. The following four general categories of TA design and implementation challenges were frequently found:

- Ensuring the design and implementation of TAs result in useful products for Congress and other policymakers[31]
- Determining the policy objective and measuring effect
- Researching and communicating complicated issues
- Engaging relevant stakeholders

[31]In order to ensure the design and implementation of TAs result in useful products for Congress and other policymakers, teams may need to first address other challenges, such as determining whether there will be any policy objectives, researching and communicating complicated issues, and engaging relevant stakeholders.

3.1 Ensuring the Design and Implementation of Technology Assessments Result in Useful Products for Congress and Other Policymakers

Teams may face challenges in designing and implementing TAs that result in products that are readable and timely. Table 5 provides examples of potential mitigation strategies to address these challenges.[32]

Table 5: Challenges to Ensuring the Design and Implementation of Technology Assessments Result in Useful Products for Congress and Other Policymakers

Specific example of a challenge	Potential mitigation strategies
Writing simply and clearly about technical subjects	• Allow sufficient time for writing and revising • Engage communication specialists to improve readability • Use “cold readers”
Technology assessments (TA) do not have a uniform design approach	• Review TA literature and discuss approaches with a broad variety of government, academic, and private sources, to get a sense of what others have done • Engage methodologists and other subject matter experts early
Threats to independence	• Ensure transparency and discuss threats (potential and real) early and often • Regularly consult with internal and external stakeholders to identify and address potential conflicts of interest • Weigh and assess stakeholder input to avoid undue influence
Determining scope for a technology with broad applications or implications	• Review literature to get a firm understanding of what has and has not been done • Prepare an initial document with a list of potential scope(s), outline trade-offs associated with each, and discuss with stakeholders • Consider performing a situation analysis to make decisions about scope, refer to Chapter 2
Length of time required to conduct, draft, and publish TAs	• Continue to explore other approaches to designing TAs, and learn from past work • Publish findings as they become available, such as publishing findings in more than one product over time • Allocate additional time for working with sensitive information, including time needed to adhere to additional policies and procedures

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

[32]Teams may also consider developing a communications or dissemination plan to ensure that the results of a TA product are available and accessible to Congress and others.

3.2 Determining the Policy Objective and Measuring Potential Effects

Another challenge in TA design arises from determining a policy objective and policy options, and estimating their potential effects. Many of the effects of policy decisions may be distant, and policy outcomes may be uncertain at the time of the TA. Table 6 provides examples of potential mitigation strategies to address these challenges.

Table 6: Challenges to Determining the Policy Objective and Measuring Potential Effects

Specific example of a challenge	Potential mitigation strategies
Policy objective and options may be difficult to identify	• Determine and communicate scope early on • Perform a literature search and engage stakeholders and experts • Conduct an analysis of the social and legal context
Effects of policy options can be uncertain and difficult to estimate	• Perform and document regular monitoring of the technology assessment subject area, such as by ongoing review of literature and engagement of relevant stakeholders, to ensure knowledge is current and sufficiently comprehensive • Make assumptions and limitations clear for each policy option • Assess and communicate level of uncertainty (e.g., high-, mid-, and low-range estimates or “best case,” “likely case,” “worst case” scenarios) • Consider and select appropriate prediction models • Consider and refer to results tracking tools and other resources, as appropriate

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

3.3 Researching and Communicating Complicated Issues

TAs are complex and interdisciplinary, and emerging technologies are inherently difficult to assess. Table 7 provides examples of potential mitigation strategies to address these challenges.

Table 7: Challenges to Researching and Communicating Complicated Issues

Specific example of a challenge	Potential mitigation strategies
Interdisciplinary nature of technology assessments (TA) can present challenges to effective communication and shared understanding	• Manage staffing effectively by making sure appropriate disciplines are represented on the TA team • Collaborate and consult among disciplines frequently and encourage open debate at regular team meetings • Consider how best to obtain expert and other stakeholder input and share information, such as through expert meetings, surveys, and interviews
Assessing complex systems	• Carefully scope the work to respond to Congressional interest in a comprehensive manner, while considering multiple products or means of communication, if necessary • Consider approaches taken by other TA teams over the past few years to inform scope and design
Assessing emerging technologies	• Determine what is known and not known, including available data sources • Leverage existing tools and data analyses if they exist. If not, extrapolate, where possible • Consider roadmapping, among other tools

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

3.4 Engaging Relevant Stakeholders

An additional challenge in conducting TAs is engaging relevant internal and external stakeholders. Table 8 provides examples of potential mitigation strategies to address this challenge.

Table 8: Challenges to Engaging Relevant Stakeholders

Specific example of a challenge	Potential mitigation strategies
Ensuring all relevant internal stakeholders are engaged	• Consider if and how the different types of internal stakeholders will be engaged • Speak with internal subject matter experts to determine which, if any, other stakeholders may need to be engaged. Also, review previous work related to the technology
Ensuring relevant external stakeholders are engaged	• Review literature and ask external experts which other external experts should be engaged • Use a systematic approach to identifying and engaging with experts known to have particular knowledge and insight. Consider reaching out to a variety of groups, such as: legislative bodies, government agencies, nongovernmental organizations, standards-setting organizations, industry, professional associations, and other groups. • Seek out stakeholders who have different points of view, where appropriate. This could include international perspectives as well as populations who could be affected by the technology in disparate ways. • Consider providing a communications channel or process whereby diverse stakeholders can regularly provide input. For example, this may be an email address or point of contact. This may also include using "open innovation" approaches such as crowdsourcing[a]

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

[a]Crowdsourcing is the practice of obtaining information or input into a task or project by enlisting the services of a large number of people, either paid or unpaid, typically via the internet. For more information, see: GAO, *Open Innovation: Executive Branch Developed Resources to Support Implementation, but Guidance Could Better Reflect Leading Practices*, GAO-17-507 (Washington, D.C.: June 8, 2017) and GAO, *Open Innovation: Practices to Engage Citizens and Effectively Implement Federal Initiatives*, GAO-17-14 (Washington, D.C.: Oct. 13, 2016).

Appendix I: Objectives, Scope, and Methodology

This handbook identifies key steps and considerations in designing technology assessments (TA). Below is a summary of methodologies used for all chapters of the handbook.

Review of Select GAO Documents

We reviewed GAO documents, including:

- *Designing Evaluations* (GAO-12-208G)
- published GAO TAs
- GAO products utilizing policy analysis approaches to identify and assess policy options
- other GAO documents

We reviewed and analyzed 20 GAO TAs,[33] including their designs and considerations, using a data collection instrument that contained fields regarding each report's purpose, methodologies, and key considerations for each methodology used (such as strengths and weaknesses). The data collection instrument also contained fields regarding whether policy considerations were presented or if specific policy options were identified and assessed in each TA report, what methodologies were used to identify and assess policy options, and key considerations associated with the methodologies used.

We also reviewed GAO reports from non-TA product lines that utilized policy analysis approaches to assess policy options. An initial pool of 56 GAO reports was generated based on a keyword search of GAO's reports database. Of the 56 GAO reports, 12 were selected for review based on the following criteria: (1) the reports were publicly released after January 1, 2013, and (2) the reports included identification and assessment of policy options (not solely a presentation of agency actions related to policy options or general policy considerations). Testimonies and

[33]All technology assessment reports on GAO's technology assessment web page (https://www.gao.gov/technology_and_science#t=1) were selected for review, as of December 2020.

correspondence were excluded. We analyzed each of these selected GAO reports according to a data collection instrument that contained the following fields regarding policy options in the report: purpose, methodologies, and key considerations for each methodology used (such as strengths and weaknesses). A list of GAO documents reviewed is provided below.

GAO Documents Reviewed for this Handbook

Artificial Intelligence in Health Care: Benefits and Challenges of Technologies to Augment Patient Care. GAO-21-7SP. Washington, D.C.: November 30, 2020.

5G Wireless: Capabilities and Challenges for an Evolving Network. GAO-21-26SP. Washington, D.C.: November 24, 2020.

COVID-19: Data Quality and Considerations for Modeling and Analysis. GAO-20-635SP. Washington, D.C.: July 30, 2020.

Forensic Technology: Algorithms Used in Federal Law Enforcement. GAO-20-479SP. Washington, D.C.: May 12, 2020.

Artificial Intelligence in Health Care: Benefits and Challenges of Machine Learning in Drug Development. GAO-20-215SP. Washington, D.C.: December 20, 2019.

Irrigated Agriculture: Technologies, Practices, and Implications for Water Scarcity. GAO-20-128SP. Washington, D.C.: November 12, 2019.

Retirement Security: Some Parental and Spousal Caregivers Face Financial Risks. GAO-19-382. Washington, D.C.: May 1, 2019.

GAO Science, Technology Assessment, and Analytics Team: Initial Plan and Considerations Moving Forward. Washington, D.C.: April 10, 2019.

Retirement Savings: Additional Data and Analysis Could Provide Insight into Early Withdrawals. GAO-19-179. Washington, D.C.: March 28, 2019.

Critical Infrastructure Protection: Protecting the Electric Grid from Geomagnetic Disturbances. GAO-19-98. Washington, D.C.: December 19, 2018.

Postal Retiree Health Benefits: Unsustainable Finances Need to Be Addressed. GAO-18-602. Washington, D.C.: August 31, 2018.

Data Collection Seminar Participant Manual. Washington, D.C.: March 2018.

Artificial Intelligence: Emerging Opportunities, Challenges and Implications. GAO-18-142SP. Washington, D.C.: March 28, 2018.

Chemical Innovation: Technologies to Make Processes and Products More Sustainable. GAO-18-307. Washington, D.C.: February 8, 2018.

Federal Regulations: Key Considerations for Agency Design and Enforcement Decisions. GAO-18-22. Washington, D.C.: October 19, 2017.

Medical Devices: Capabilities and Challenges of Technologies to Enable Rapid Diagnoses of Infectious Diseases. GAO-17-347. Washington, D.C.: August 14, 2017.

U.S. Postal Service: Key Considerations for Potential Changes to USPS's Monopolies. GAO-17-543. Washington, D.C.: June 22, 2017.

Internet of Things: Status and Implications of an Increasingly Connected World. GAO-17-75. Washington, D.C.: May 15, 2017.

Flood Insurance: Comprehensive Reform Could Improve Solvency and Enhance Resilience. GAO-17-425. Washington, D.C.: April 27, 2017.

Flood Insurance: Review of FEMA Study and Report on Community-Based Options. GAO-16-766. Washington, D.C.: August 24, 2016.

Medicaid: Key Policy and Data Considerations for Designing a Per Capita Cap on Federal Funding. GAO-16-726. Washington, D.C.: August 10, 2016.

Municipal Freshwater Scarcity: Using Technology to Improve Distribution System Efficiency and Tap Nontraditional Water Sources. GAO-16-474. Washington, D.C.: April 29, 2016.

GAO Memorandum: Quality Assurance Framework Requirements for Technology Assessments. Washington, D.C.: April 6, 2016.

Biosurveillance: Ongoing Challenges and Future Considerations for DHS Biosurveillance Efforts. GAO-16-413T. Washington, D.C.: February 11, 2016.

Social Security's Future: Answers to Key Questions. GAO-16-75SP. Washington, D.C.: October 2015.

Water in the Energy Sector: Reducing Freshwater Use in Hydraulic Fracturing and Thermoelectric Power Plant Cooling. GAO-15-545. Washington, D.C.: August 7, 2015.

Nuclear Reactors: Status and Challenges in Development and Deployment of New Commercial Concepts. GAO-15-652. Washington, D.C.: July 28, 2015.

Veterans' Disability Benefits: Improvements Needed to Better Ensure VA Unemployability Decisions Are Well Supported. GAO-15-735T. Washington, D.C.: July 15, 2015.

Debt Limit: Market Response to Recent Impasses Underscores Need to Consider Alternative Approaches. GAO-15-476. Washington, D.C.: July 9, 2015.

Temporary Assistance for Needy Families: Potential Options to Improve Performance and Oversight. GAO-13-431. Washington, D.C.: May 15, 2013.

Private Pensions: Timely Action Needed to Address Impending Multiemployer Plan Insolvencies. GAO-13-240. Washington, D.C.: March 28, 2013.

Designing Evaluations: 2012 Revision. GAO-12-208G. Washington, D.C.: January 2012.

Neutron Detectors: Alternatives to Using Helium-3. GAO-11-753. Washington, D.C.: September 3, 2011.

Climate Engineering: Technical Status, Future Directions, and Potential Responses. GAO-11-71. Washington, D.C.: July 28, 2011.

Technology Assessment: Explosives Detection Technologies to Protect Passenger Rail. GAO-10-898. Washington, D.C.: July 28, 2010.

Technology Assessment: Protecting Structures and Improving Communications during Wildland Fires. GAO-05-380. Washington, D.C.: April 26, 2005.

Technology Assessment: Cybersecurity for Critical Infrastructure Protection. GAO-04-321. Washington, D.C.: May 28, 2004.

Technology Assessment: Using Biometrics for Border Security. GAO-03-174. Washington, D.C: November 15, 2002.

Review of Select Office of Technology Assessment Reports

A GAO librarian performed a search for relevant Office of Technology Assessment (OTA) reports, using keyword searches.[34] From this initial list of OTA reports, we selected 17 reports to review that were frameworks, guides, models, or other compilations. We also reviewed the methodologies of the OTA reports selected for review. A list of OTA reports reviewed is included below.

Office of Technology Assessment Reports Reviewed for this Handbook

Office of Technology Assessment. *Insider's Guide to OTA*. Washington, D.C.: January 1995.

Office of Technology Assessment. *Policy Analysis at OTA: A Staff Assessment.* Washington, D.C.: May 1993.

Office of Technology Assessment. *Research Assistants Handbook.* Washington, D.C.: June 1992.

Office of Technology Assessment. *Strengths and Weaknesses of OTA Policy Analysis.* Washington, D.C.: 1992.

[34]Websites searched for OTA reports included: http://ota.fas.org/technology_assessment_and_congress/, https://www.princeton.edu/~ota/, and https://digital.library.unt.edu.

Office of Technology Assessment. *The OTA Orange Book: Policies and Procedures of the Office of Technology Assessment: Communication with Congress and the Public.* Washington, D.C.: February 1986.

Office of Technology Assessment. *What OTA Is, What OTA Does, How OTA Works.* Washington, D.C.: March 1983.

Office of Technology Assessment. *Draft: An OTA Handbook.* Washington, D.C.: June 7, 1982.

Office of Technology Assessment. *Draft: A Management Overview Methodology for Technology Assessment.* Washington, D.C.: February 2, 1981.

Office of Technology Assessment. *Draft: Technology Assessment in Industry: A Counterproductive Myth.* Washington, D.C.: January 30, 1981.

Office of Technology Assessment. *Draft: Technology Assessment Methodology and Management Practices.* Washington, D.C.: January 12, 1981.

Office of Technology Assessment. *Draft: Technology Assessment in the Private Sector.* Washington, D.C.: January 9, 1981.

Office of Technology Assessment. *Draft: A Process for Technology Assessment Based on Decision Analysis.* Washington, D.C.: January 1981.

Office of Technology Assessment. *Draft: Technology as Social Organization.* Washington, D.C.: January 1981.

Office of Technology Assessment. *A Summary of the Doctoral Dissertation: A Decision Theoretic Model of Congressional Technology Assessment.* Washington, D.C.: January 1981.

Office of Technology Assessment. *Report on Task Force Findings and Recommendations: Prepared by the OTA Task Force on TA Methodology and Management.* Washington, D.C.: August 13, 1980.

Office of Technology Assessment. *Phase I Survey Results: Draft Papers Prepared for the Task Force on TA Methodology and Management.* Washington, D.C.: April 10, 1980.

Office of Technology Assessment. *Staff Memo: Notes and Comments on Staff Discussion of Task Force on TA Methodology and Management.* Washington, D.C.: December 14, 1979.

Review of Select Congressional Research Service Reports

We identified 29 Congressional Research Service (CRS) reports to consider reviewing that were TAs or included an analysis of policy options, based on a keyword search of CRS's website.[35] We also interviewed CRS officials. Of the initial 29 CRS reports we identified, we selected six CRS reports to review, based on the following criteria: (1) published within the past 15 years (2004-2019) and (2) if a review of technology (technology assessment) and/or policy options was included. Reports were excluded based on the following criteria: (1) for technology assessment related reports—if they represented a summary of a technology assessment that was included in our review or (2) for policy options related reports—the report did not indicate how CRS arrived at the policy options (no methodology to review or analyze). A list of CRS reports reviewed is included below.

Congressional Research Service Reports Reviewed for this Handbook

Congressional Research Service. *Advanced Nuclear Reactors: Technology Overview and Current Issues.* Washington, D.C.: April 18, 2019.

Congressional Research Service. *Drug Shortages: Causes, FDA Authority, and Policy Options.* Washington, D.C.: December 27, 2018.

Congressional Research Service. *Policy Options for Multiemployer Defined Benefit Pension Plans.* Washington, D.C.: September 12, 2018.

Congressional Research Service. *Shale Energy Technology Assessment: Current and Emerging Water Practices.* Washington, D.C.: July 14, 2014.

Congressional Research Service. *Carbon Capture: A Technology Assessment.* Washington, D.C.: November 5, 2013.

[35]The following CRS website was used: http://www.loc.gov/crsinfo/.

Congressional Research Service. *Energy Storage for Power Grids and Electric Transportation: A Technology Assessment.* Washington, D.C.: March 27, 2012.

Review of Select Literature

A GAO librarian and the engagement team performed a literature search of English-language publications based on keyword searches for two areas—TA and policy options. For TA literature, the team selected 29 documents to review that were frameworks, guides, models, or other compilations, based on a review of the literature titles and abstracts. In general, we excluded non-English literature, as well as literature that represented specialized types of TAs, such as health-related TAs (we focused on TA design more broadly). For policy options literature, the team selected 14 documents to review that were frameworks, guides, models, or other compilations and focused on policy options related to science and technology. We also asked experts we consulted to suggest literature for our review; these suggestions confirmed the literature list noted below, along with any additional relevant literature that was published since the initial TA Design Handbook was published in December 2019 (that represents 11 additional documents). A list of literature reviewed is included below.

Literature Reviewed for this Handbook

Pennock, M.J., and D.A. Bodner. “A Methodology for Modeling Sociotechnical Systems to Facilitate Exploratory Policy Analysis.” *Systems Engineering*, vol. 23 (2020): p. 409-422.

Kariotis, T.C., and D. J. Mir. “Fighting Back Algocracy: The Need for New Participatory Approaches to Technology Assessment.” *In Proceedings of the 16th Participatory Design Conference, June 15-20, 2020*. Association for Computing Machinery (2020): p. 148-153.

Chodakowska, E. “A Hybrid Approach in Future-Oriented Technology Assessment.” *In Proceedings of the Future Technologies Conference (FTC). Advances in Intelligent Systems and Computing*, vol. 1069 (2020): p. 512-525.

Ndiaye, S.A.R. “Giving Youth a Seat at the Table: Considerations from Existing Frameworks of Youth Participation in Public Policy Decision-making.” *Youth Voice Journal* (2020): p. 11-24.

Bartels, K.P.R., D. J. Greenwood, and J. M. Wittmayer. “How Action Research Can Make Deliberative Policy Analysis More Transformative.” *Policy Studies*, vol. 41 (2020): p. 392-410.

Weber, K.M., N. Gudowsky, and G. Aichholzer. “Foresight and Technology Assessment for the Austrian Parliament — Finding New Ways of Debating the Future of Industry 4.0.” *Futures*, vol. 109 (2019): p. 240-251.

Haleem, A., B. Mannan, S. Luthra, S. Kumar, and S. Khurana. “Technology Forecasting (TF) and Technology Assessment (TA) Methodologies: a Conceptual Review.” *Benchmarking*, vol. 26 (2019): p. 48-72.

Grunwald, Armin. *Technology Assessment in Practice and Theory.* London and New York: Routledge, 2019.

Armstrong, Joe E., and Willis W. Harman*. Strategies For Conducting Technology Assessments.* London and New York: Routledge, 2019.

Noh, Heeyong, Ju-Hwan Seo, Hyoung Sun Yoo, and Sungjoo Lee. “How to Improve a Technology Evaluation Model: A Data-driven Approach.” *Technovation*, vol. 72/73 (2018): p. 1-12.

Larsson, A., T. Fasth, M. Wärnhjelm, L. Ekenberg, and M. Danielson. “Policy Analysis on the Fly With an Online Multicriteria Cardinal Ranking Tool.” *Journal of Multi-Criteria Decision Analysis*, vol. 25 (2018): p. 55-66.

Nooren, P., N. van Gorp, N. van Eijk, and R. O. Fathaigh. “Should We Regulate Digital Platforms? A New Framework for Evaluating Policy Options.” *Policy and Internet*, vol. 10, no. 3 (2018): p. 264-301.

Smith, A., K. Collins, and D. Mavris. “Survey of Technology Forecasting Techniques for Complex Systems.” Paper presented at *58th AIAA/ASCE/AHS/ASC Structures, Structural Dynamics, and Materials Conference*, Grapevine, TX (2017).

Ibrahim, O., and A. Larsson. “A Systems Tool for Structuring Public Policy Problems and Design of Policy Options.” *Int. J. Electronic Governance*, vol. 9 , nos. 1/2 (2017): p. 4-26.

Christopher, A. Simon. *Public Policy Preferences and Outcomes.* 3rd ed. New York: Routledge, 2017.

Weimer, David L., and R. Aidan Vining. *Policy Analysis Concepts and Practice.* 6th ed. London and New York: Routledge, 2017.

Mulder, K. “Technology Assessment.” *In Foresight in Organizations: Methods and Tools*, edited by Van Der Duin, Patrick, 109-124, 2016.

Coates, Joseph F. “A 21st Century Agenda for Technology Assessment.” *Technological Forecasting and Social Change*, vol. 113 part A (2016): p. 107-109.

Coates, Joseph F. “Next Stages in Technology Assessment: Topics and Tools.” *Technological Forecasting and Social Change*, vol. 113 (2016): p. 112-114.

Mazurkiewicz, A., B. Belina, B. Poteralska, T. Giesko, and W. Karsznia. “Universal Methodology for the Innovative Technologies Assessment.” *Proceedings of the European Conference on Innovation and Entrepreneurship* (2015): p. 458-467.

Sadowski, J. “Office of Technology Assessment: History, Implementation, and Participatory Critique.” *Technology in Society*, vol. 42 (2015): p. 9-20.

Larsson, A., O. Ibrahim. “Modeling for Policy Formulation: Causal Mapping, Scenario Generation, and Decision Evaluation.” In *Electronic Participation: 7th IFIP 8.5 International Conference*, 135-146, Springer, 2015.

Moseley, C., H. Kleinert, K. Sheppard-Jones, and S. Hall. “Using Research Evidence to Inform Public Policy Decisions.” *Intellectual and Developmental Disabilities*, vol. 51 (2013): p. 412-422.

Calof, J., R. Miller, and M. Jackson. “Towards Impactful Foresight: Viewpoints from Foresight Consultants and Academics.” *Foresight*, vol. 14 (2012): p. 82-97.

Parliaments and Civil Society in Technology Assessment, *Collaborative Project on Mobilization and Mutual Learning Actions in European Parliamentary Technology Assessment*. EPTA-PACITA, 2012.

Parliamentary Technology Assessment in Europe. *An Overview of 17 Institutions and How They Work.* EPTA, November 2012.

Blair, P. D. “Scientific Advice for Policy in the United States: Lessons from the National Academies and the Former Congressional Office of Technology Assessment.” In *The Politics of Scientific Advice: Institutional Design for Quality Assurance*, ed. Lentsch, Justus, 297-333, 2011.

Paracchini, M.L., C. Pacini, M.L.M. Jones, and M. Pérez-Soba. “An Aggregation Framework to Link Indicators Associated With Multifunctional Land Use to the Stakeholder Evaluation of Policy Options.” *Ecological Indicators*, vol. 11 (2011): p 71-80.

Roper, A. T., S. W. Cunningham, A. L. Porter, T. W. Mason, F. A. Rossini, and J. Banks. *Forecasting and Management of Technology*, 2nd ed. New Jersey: Wiley, 2011.

Lepori, B., E. Reale, and R. Tijssen. “Designing Indicators for Policy Decisions: Challenges, Tensions and Good Practices: Introduction to a Special Issue.” *Research Evaluation*, vol. 20, no. 1 (2011): p. 3-5.

te Kulve, H., and A. Rip. “Constructing Productive Engagement: Pre-engagement Tools for Emerging Technologies.” *Science and Engineering Ethics*, vol. 17 (2011): p. 699-714.

Russel, A. W., F. M. Vanclay, and H. J. Aslin H.J. “Technology Assessment in Social Context: The Case for a New Framework for Assessing and Shaping Technological Developments.” *Impact Assessment and Project Appraisal*, vol. 28, no. 2 (2010): p. 109-116.

Shiroyama, H., G. Yoshizawa, G., M. Matsuo, and T. Suzuki. “Institutional Options and Operational Issues in Technology Assessment: Lessons from Experiences in the United States and Europe.” Paper presented at *Atlanta Conference on Science and Innovation Policy*, Atlanta, 2009.

Tran, T.A., and T. Daim T. “A Taxonomic Review of Methods and Tools Applied in Technology Assessment.” *Technological Forecasting and Social Change*, vol. 75 (2008): p. 1396-1405.

Brun, G., and G. Hirsch Hadorn. “Ranking Policy Options for Sustainable Development.” *Poiesis Prax*, vol. 5 (2008): p. 15-31.

Robinson, D.K.R., and T. Propp. “Multi-path mapping for alignment strategies in emerging science and technologies.” *Technological Forecasting and Social Change*, vol. 75, no. 4 (2008): p. 517-538.

Tran, T.A. “Review of Methods and Tools applied in Technology Assessment Literature.” Paper presented at *Portland International Conference on Management of Engineering and Technology*, Portland Oregon, 2007.

Burgess, J., A. Stirling, J. Clark, G. Davies, M. Eames, K. Staley, and S. Williamson. “Deliberative Mapping: A Novel Analytic-Deliberative Methodology to Support Contested Science-Policy Decisions.” *Public Understanding of Science*, vol. 16 (2007): p. 299-322.

Decker, M., and M. Ladikas. *Bridges Between Science, Society and Policy: Technology Assessment — Methods and Impacts*, Berlin: Springer-Verlag, 2004.

Guston, D. H., and D. Sarewitz. “Real-time Technology Assessment.” *Technology in Society*, vol. 24 (2002): p. 93-109.

Rip, A. “Technology Assessment.” In *International Encyclopedia of the Social & Behavioral Science*, vol. 23, edited by Smelster, N. J. and B. P. Baltes, 15512-15515. Amsterdam: Elsevier, 2001.

Kostoff, R.N., and R.R. Schaller. “Science and Technology Roadmaps.” *IEEE Transactions on Engineering Management*, vol 48, no. 2 (2001): p. 132-143.

Van Den Ende, J., K. Mulder, M. Knot, E. Moors, and P. Vergragt. “Traditional and Modern Technology Assessment: Toward a Toolkit.” *Technological Forecasting and Social Change*, vol. 58 (1998): p. 5-21.

Wood, F. B. “Lessons in Technology Assessment: Methodology and Management at OTA.” *Technological Forecasting and Social Change*, vol. 54 (1997): p. 145-162.

Janes, M. C. “A Review of the Development of Technology Assessment.” *International Journal of Technology Management*, vol. 11, no. 5-6 (1996): p. 507-522.

Hastbacka, M. A., and C. G. Greenwald. “Technology Assessment - Are You Doing it Right?” *Arthur D. Little – PRISM*, no. 4 (1994).

Rivera, W. M., D. J. Gustafson, and S. L. Corning. “Policy Options in Developing Agricultural Extension Systems: A Framework for Analysis.” *International Journal of Lifelong Education*, vol. 10, no. 1 (1991): p. 61-74.

Lee, A. M., and P. L. Bereano. “Developing Technology Assessment Methodology: Some Insights and Experiences.” *Technological Forecasting and Social Change*, vol. 19 (1981): p. 15-31.

Porter, A. L., F. A. Rossini, S. R. Carpenter, and A. T. Roper. *A Guidebook for Technology Assessment and Impact Analysis*, vol. 4. New York and Oxford: North Holland, 1980.

Pulver, G.C. “A Theoretical Framework for the Analysis of Community Economic Development Policy Options.” In *Nonmetropolitan Industrial Growth and Community Change*, edited by Summers, G. and A. Selvik, 105-117. Massachusetts and Toronto: Lexington Books, 1979.

Ascher, W. “Problems of Forecasting and Technology Assessment.” *Technological Forecasting and Social Change*, vol. 13, no. 2 (1979): p. 149-156.

Majone, G. “Technology Assessment and Policy Analysis.” *Policy Sciences*, vol. 8, no. 2 (1977): p. 173-175.

Berg, M., K. Chen, and G. Zissis. “A Value-Oriented Policy Generation Methodology for Technology Assessment.” *Technological Forecasting and Social Change*, vol. 4, no. 4 (1976): p. 401-420.

Lasswell, Harold D. A Pre-View of Policy Sciences. *Policy Sciences Book Series.* New York: Elsevier, 1971.

Expert Meeting

We held an expert meeting in September 2019 to gather experts’ opinions regarding TA design. To do this, we prepared an initial list of experts based on a review of GAO TA reports, literature, and referral by other experts. We then selected experts based on their knowledge and expertise in the subject, including: (1) prior participation on a National Academies panel or other similar meeting; (2) leadership position in one or more organizations or sectors relevant to technology research and development implementation or policy; and (3) relevant publications or sponsorship of reports. Care was also taken to ensure a balance of sectors, backgrounds, and specific areas of expertise (e.g., science, technology, policy, information technology, and law). We also asked the experts to suggest literature for our review; these suggestions confirmed

the literature list noted above. A list of external experts consulted is included below.

Expert Meeting Participants

Dr. Jeffrey M. Alexander, Senior Manager, Innovation Policy, RTI International

Dr. Robert D. Atkinson, President, Information Technology and Innovation Foundation

Mr. David Bancroft, Executive Director, International Association for Impact Assessment

Mr. Duane Blackburn, S&T Policy Analyst, Office of the CTO, MITRE

Dr. Peter D. Blair, Executive Director, Division of Engineering and Physical Sciences, National Academies of Sciences, Engineering, and Medicine

Ms. Marjory Blumenthal, Acting Associate Director, Acquisition and Technology Policy Center; Senior Policy Researcher, RAND Corporation

Mr. Chris J. Brantley, Managing Director, Institute of Electrical and Electronics Engineers, Inc., USA

Dr. Jonathan P. Caulkins, H. Guyford Stever University Professor of Operations Research and Public Policy, Carnegie Mellon University

Mr. Dan Chenok, Executive Director, Center for The Business of Government, IBM

Dr. Gerald Epstein, Distinguished Research Fellow, Center for the Study of Weapons of Mass Destruction, National Defense University

Dr. Robert M. Friedman, Vice President for Policy and University Relations, J. Craig Venter Institute

Mr. Zach Graves, Head of Policy, Lincoln Network

Ms. Allison C. Lerner, Inspector General, National Science Foundation

Mr. Mike Molnar, Director of Office of Advanced Manufacturing, National Institute of Standards and Technology

Dr. Michael H. Moloney, CEO, American Institute of Physics

Dr. Ali Nouri, President, Federation of American Scientists

Dr. Jon M. Peha, Professor, Engineering and Public Policy; Courtesy Professor, Electrical and Computer Engineering, Carnegie Mellon University

Dr. Stephanie S. Shipp, Deputy Director and Professor, University of Virginia, Biocomplexity Institute and Initiative, Social and Decision Analytics Division

Dr. Daniel Sarewitz, Co-Director, Consortium for Science, Policy & Outcomes Professor of Science and Society, School for the Future of Innovation in Society, Arizona State University

Ms. Rosemarie Truman, Founder and CEO, Center for Advancing Innovation

Dr. Chris Tyler, Director of Research and Policy, Department of Science, Technology, Engineering and Public Policy (STEaPP), University College London (UCL)

Mr. David E. Winickoff, Senior Policy Analyst and Secretary of the Working Party on Bio-, Nano- and Converging Technology, Organisation for Economic Co-operation and Development

Additional Expert Outreach

After the initial handbook was published, we performed additional outreach to external experts. Specifically, we sought feedback from: (1) experts with whom GAO had previously consulted for its TA work, including those who participated in GAO forums and advisory meetings, and those who provided comments on a TA product since 2015; (2) experts who provided input on the initial handbook in 2019; (3) experts consulted as part of GAO's ongoing TA work; and (4) other expert groups, such as members of the European Parliamentary Technology Assessment network.

Public Comment

After publication of the initial handbook in December 2019, we solicited comments for approximately 1 year. We received comments from former OTA officials, academia, private companies, and the general public. We incorporated comments, as applicable.

Review of Experiences of GAO Teams

We spoke with and gathered input from GAO teams that are in the process of or have successfully assessed and incorporated policy options into GAO products. In addition, to augment our understanding of TA design and implementation challenges, we collected input from GAO staff who had provided key contributions to GAO TAs. Specifically, we asked for their thoughts regarding: (1) the strengths and limitations of TA methodologies and (2) challenges they faced, and strategies to address those challenges.

In addition, we gathered input from GAO staff to identify additional lessons learned after the publication of the initial handbook in December 2019.[36] Specifically, we conducted semi-structured discussions with senior GAO management, attorneys from GAO's Office of General Counsel, technical specialists, methodologists, and analysts who contributed to at least one TA product published since October 2019.

[36]GAO, *Technology Assessment Design Handbook*, GAO-20-246G (Washington, D.C.: Dec. 4, 2019).

Appendix II: GAO's Expertise with Technology Assessments

GAO has conducted science and technology (S&T) work for close to 50 years, including technology assessments for almost two decades. In 2018, Congress encouraged GAO to form an S&T-focused team, recognizing that the scope of technological complexities continues to grow significantly and there is need to bolster capacity of, and enhance access to, quality, independent science and technological expertise for Congress. On January 29, 2019, GAO formally created the Science, Technology Assessment, and Analytics (STAA) team by pulling together and building upon existing elements and expertise within GAO.

STAA teams are made up of interdisciplinary staff with expertise in policy analysis and various technical fields including science, technology, engineering, mathematics, technology readiness assessment, operations research, and life cycle cost estimating. Many STAA staff hold advanced degrees in one or more of these areas. STAA continues to innovate and experiment with product formats to meet client and other needs, including shorter and more rapidly produced product formats. For example, STAA teams are agile and capable of providing rapid responses to questions from individual Members and committees on S&T topics.[37] Further, in 2019, STAA launched GAO's Science & Tech Spotlight product line. These products are two-page overviews for policymakers and the public that describe an emerging S&T development, the opportunities and challenges it brings, and relevant policy context and are completed in short time frames. Since its creation, STAA has provided over 50 products to Congress, including technology assessments (TA) covering a wide range of science, technology, and information technology issues.

STAA, as part of GAO, also benefits from access to a wide array of additional specialists and subject matter experts regarding an array of federal programs. These include policy analysts, economists, social scientists, methodologists, and attorneys across GAO's 14 other mission teams. GAO ensures internal knowledge transfer by sharing lessons learned and working collaboratively across its mission teams. Furthermore, with 11 field offices, GAO has access to specialists from

[37]Technical assistance includes, but is not limited to, briefings on prior or ongoing work, responses to technical questions, short-term analysis of agency programs or activities, detailed follow-up, and hearing support.

across the country, as well as diverse universities, research institutions, and industries. STAA has worked collaboratively with other teams at GAO on about 275 products since its creation.

GAO has long-established, robust organizational processes and procedures to ensure work is independent, high quality, and nonpartisan. GAO's core values—accountability, integrity, and reliability—form the basis for all the agency's work, regardless of its origin. Across product lines, GAO uses robust quality standards to help ensure independence in its work, including in GAO TAs.[38]

GAO and STAA benefits from regular engagement with outside experts. For example, GAO's TAs traditionally include extensive and ongoing engagement with relevant external experts.[39] Further, GAO draws on expertise from scientists, engineers, and physicians through regular engagement with the National Academies of Sciences, Engineering, and Medicine. To this end, since 2001, GAO has contracted with the National Academies to help identify experts on various scientific topics, and leverage National Academies' assistance to convene GAO expert meetings.

[38]For example, GAO senior managers annually review employees' financial holdings and other interests. In addition, employees must certify every 2 weeks that they remain independent with respect to their assigned work. If any potential conflict or concern arises, supervisors, in conjunction with GAO's Office of Ethics, take immediate and appropriate action. GAO also conducts internal inspections and other efforts to ensure independence. Likewise, GAO congressional protocols help maintain independence from Congress while being responsive to congressional needs.

[39]For example, as a general practice with its TAs, GAO selects and regularly engages a cross-sectoral group of experts with relevant backgrounds to gather opinions and discuss the latest research in the field, such as by convening a meeting of experts. GAO continues to engage these experts over the course of the work to gain additional input, such as reviewing the draft product for technical and scientific accuracy.

In addition, to further enhance engagement with the broader science, technology, and policy community, GAO recently formed the Polaris Council to advise STAA's S&T products, management, and outreach.[40] The Council consists of a group of cross-sectoral S&T policy experts who will provide long-term, multidimensional advice and assistance to help ensure that we provide relevant, nonpartisan foresight, insight, and oversight on key issues and related policy implications for Congress and the public.

[40]In October 2020, GAO established the Polaris Council, a body of interdisciplinary S&T policy experts, to advise the agency on emerging S&T issues facing Congress and the nation. GAO also relies on other advisory bodies to ensure access to a broad, external knowledge base when planning and conducting work, including the Comptroller General's Advisory Board, the Educators Advisory Panel, the Executive Council on Information Management and Technology, and the Accountability Advisory Council. More recently, GAO created the Center for Strategic Foresight to enhance its ability to identify, monitor, and analyze emerging issues and their implications for Congress, as well as the Innovation Lab under STAA, to accelerate the application of advanced data science across GAO mission areas.

Appendix III: Summary of Steps for GAO's General Engagement Process

As part of GAO's quality standards, GAO's general design and project plan templates contain five phases that are followed in sequential order, with ongoing review and modifications or changes as needed. GAO technology assessments (TA) use these templates. Throughout the phases, the status of the work, including decisions, is communicated to stakeholders and congressional committees that requested the work. Provided below is a summary of the activities GAO staff undertake during each of the phases, and is based on a review of GAO documentation related to engagement phases.[41]

- Phase I: Acceptance
  - Engagement characteristics such as risk level or internal stakeholders are determined at a high-level Engagement Acceptance Meeting.
  - Staff obtain a copy of and review the congressional request letter(s), as applicable.[42]
- Phase II: Planning and Proposed Design
  - Staff are assigned to the engagement and set up the electronic engagement documentation folders.

[41]"Engagement" is the term GAO uses for its audit and non-audit work and for producing reports, testimonies, technology assessments, and other products. Engagements are generally performed at the request of congressional committee(s) or the Comptroller General.

[42]GAO performs work for Congress that is initiated through requests, legislation (i.e., statutory mandates), and Comptroller General Authority (i.e., GAO-initiated work). In addition, GAO conducts work in response to requests for technical assistance (e.g., briefings on prior or ongoing work, responses to technical questions, short-term analysis of agency programs or activities, detailed follow-up, and hearing support).

- Staff enter standard information regarding the engagement in GAO's Engagement Management System (EMS),[43] which is used to monitor the status of the engagement throughout the engagement process and regularly updated.
- Engagement team holds an initiation meeting with engagement stakeholders to discuss potential research questions, design options, and stakeholder involvement.
- Engagement team clarifies engagement objectives and approach through discussions with the congressional requesters, as applicable.
- Engagement team obtains background information. For example, to gather information about the topic and any work already performed, teams may conduct a literature review, search prior and ongoing GAO work related to the topic, or consult with external stakeholders, outside experts, and agency officials, including the Congressional Research Service, Congressional Budget Office, and Inspectors General of federal agencies.
- Engagement team formally notifies agencies of the engagement through a notification letter, and hold an entrance conference, as applicable.
- Engagement team prepares a design matrix, project plan, risk assessment tool, data reliability assessment, and all participants on engagements, including stakeholders, affirm their independence. The design matrix is a tool that describes researchable questions; criteria; information required and sources; scope and methodology; and limitations. The project plan identifies key activities and tasks, dates for completing them, and staff assigned.
- Engagement team secures approval to move forward with engagement approach at a high-level Engagement Review Meeting.

- Phase III: Evidence Gathering, Finalizing Design, and Analysis
  - Engagement team finalizes design: teams work with internal stakeholders to confirm soundness and reach agreement on proposed initial design. If engagement teams and stakeholders

[43]EMS is a web-based system that provides information on GAO engagements, such as job code, engagement title, risk level, project milestones, assigned staff, costs, and narratives related to background, scope/methodology, key questions, and potential impact/results.

conclude that additional work is needed or the design faces significant implementation challenges, design is reviewed and modified, as needed.

- Engagement team collects and analyzes evidence: teams may collect and analyze evidence using a variety of methodologies including document review, interviews, surveys, focus groups, and various forms of data analysis. For example, engagement teams may meet with agency officials and outside experts, as applicable, to gather evidence.
- Engagement team assesses evidence and agrees on conclusions: teams assess whether the evidence collected is sufficient and appropriate to support findings and conclusions reached for each objective. Once sufficient evidence is collected and analyzed, the team discusses how the evidence supports potential findings and shares these findings with stakeholders, generally in the form of a formal message agreement meeting.
- Engagement team updates congressional requesters, as applicable, on the engagement status and potential findings.

- Phase IV: Product Development
  - Engagement team drafts product: after drafting the product, teams send draft to internal stakeholders for review, including methodological and legal sufficiency reviews. Teams also send draft to relevant external parties, including relevant agencies, to confirm facts and obtain their views.
  - Engagement team identifies sources of all information in the draft and an independent analyst verifies the sources through a process called indexing and referencing.
  - Engagement team performs exit conferences with agencies, as applicable, to discuss findings and potential recommendations. Agencies and external parties are given the opportunity to comment on the draft, as applicable.
  - Engagement team incorporates final comments from agencies and external parties, as applicable, and conducts a final round of review with internal stakeholders, including methodological and legal sufficiency reviews.
  - Engagement team communicates findings and potential recommendations, as well as timeframes for issuing the product, to congressional requesters, as applicable.

    - The draft product is copy-edited, prepared for issuance, and publicly released on GAO's website, as applicable.

- Phase V: Results
    - Engagement documentation is closed out.

Engagement team conducts follow-up, tracks the results, and prepares reports on the status of recommendations and financial and non-financial benefits, as applicable, using GAO's results tracking system.

Appendix IV: Example Methods for Technology Assessment

This appendix provides examples of methods and analytical approaches that GAO teams, including technology assessment (TA) teams, can consider using to gather and examine different types of evidence. Also included in this appendix are considerations of the strengths, limitations, and synergies among evidence types and methods, which can be useful to consider throughout design to ensure that evidence is sufficient and appropriate to answer the researchable questions. Each type of evidence has benefits and limitations, and the appropriateness of a particular type of evidence will depend on the context. Examples from GAO TAs were used given our familiarity with GAO products, though numerous other (non-GAO) examples of TA methods exist. This appendix included a review of GAO reports and select literature, and is not intended to be comprehensive. This is a simplified presentation of methods, and there is variation in the levels of structure of the example methods.

This appendix is divided into several sections, including by evidentiary types: Testimonial, Documentary, and Physical. For each of these types of evidence, example methods are provided according to low and high levels of structure, and include examples of considerations (such as general benefits and limitations) that analysts may consider. In general, more highly structured approaches generate better consistency and comparability of results that allows for stronger quantification. Less structured approaches tend to provide more flexibility and context, and richer illustrative materials.

Examples of Methodologies for Testimonial Evidence

Testimonial evidence is elicited from respondents to understand their experience, opinions, knowledge, and behavior, and it can be obtained through a variety of methods, including inquiries, interviews, focus groups, expert forums, or questionnaires. Testimonial evidence can be gathered from individuals, who may be responding personally based on their own experience or in an official capacity to represent agencies or other entities; or groups, which may share individual level responses or may present a single group response. Group testimony enables interactions that can be used to explore similarities and differences among participants, to identify tensions or consensus in a group, or to

explore ideas for subsequent research and collaboration. It is important to evaluate the objectivity, credibility, and reliability of testimonial evidence. Analysts may use a combination of approaches to gather testimonial evidence, depending on the relevant population(s) of respondents, intended analytical approach(es), likely respondent burden, and resource considerations. Table 9 provides more examples.

Table 9: Select Examples of Methodologies for Testimonial Evidence

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments (TA)
Low	• Interviews • Small group discussions • Diary methods	• Qualitative data is descriptive, good for examples and anecdotal information • Semi-structured and unstructured can be developed fairly quickly • Data collected to answer “how” and “why” kinds of questions • Can be appropriate for explanatory or early design work, to inform further data collection later in the engagement (such as survey development) or to help interpret results at the end of the assignment • Can allow the team to gather lots of information and allows for follow-up questions • Allows for spontaneity and probing during interviews • Can elicit opinions of key informants, corroborate evidence from other sources, and provide leads on audits	• Conducting interviews, data reduction, and analysis of data collected from semi-structured and unstructured interviews can be time consuming • May be tempting to generalize results beyond the cases selected, which would only be appropriate when interviewing a sample designed to be generalizable • A relatively small number of cases may result in extreme responses skewing analysis • Unstructured and semi-structured items may introduce inconsistences that make reporting very difficult • Data summary/reduction and analysis can be difficult and time consuming • May not obtain results that demonstrate a consensus of opinion, common themes, or patterns	• A TA team identified how effective biometric technologies may be applied to current U.S. border control procedures, by interviewing government officials, among other methods (GAO-03-174)

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments (TA)
High	• Focus groups • Expert panels • Surveys	• Data collected may help answer "to what extent" kinds of questions • Precise estimates (with confidence intervals) can be provided when using a generalizable sample design • Techniques such as the Delphi method may be able to identify areas of consensus	• Can be more time intensive to develop structured approach • May require more technical expertise in question development, facilitation, or statistical methods • May require pre-testing of instruments to achieve reliability • Low response/collection rate can limit generalizability • Once fielded, can be hard to change	• A TA team used an expert forum comprised of individuals from academia, industry, government, and nonprofit organizations to identify and analyze emerging opportunities, challenges, and implications of artificial intelligence (GAO-18-142SP)

Source: GAO-20-246G and review of GAO technology assessments. | GAO-21-347G

Examples of Methodologies for Documentary Evidence

Documentary evidence is existing information, such as letters, contracts, accounting records, invoices, spreadsheets, database extracts, literature, electronically stored information, and management information on performance. It is important to evaluate the objectivity, credibility, and reliability of documentary evidence. Analysts may use a combination of approaches to gather documentary evidence, depending on the relevant sources and types of documents, intended analytical approach(es), and resource considerations. Table 10 provides more examples.

Table 10: Select Examples of Methodologies for Documentary Evidence

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments (TA)
Low	• Document summary • Background research • Article review	• Quantitative and qualitative, numeric and narrative information that can help to provide background knowledge or illustrate a point • Can be appropriate in early design work to help shape researchable questions and identify relevant stakeholders	• May not fully reflect important aspects of the document • May not reflect the broader population of knowledge	• A TA team reviewed key reports and scientific literature to establish background related to chemical innovation (GAO-18-307)
High	• Data collection instrument • Administrative data • Systematic literature review • Evaluation synthesis • Content analysis • Case law review • Statistical modeling	• Enables systematic data collection and gives ability to systematically analyze information from written material • Results of analysis can be easily summarized and understood • Improves ability for researchers to more easily analyze collected data • Multiple staff can collect data at the same time, if appropriately trained • Can be generalizable	• Requires preparation and testing of protocol and instrument to ensure reliability of measurement and coding • Availability and location of source records sometimes a problem • Limited flexibility during fieldwork • Abstraction and reduction of data collection can lose valuable context • Requires knowledge of method and data collection methods expertise • Can be labor- and time- intensive • May require training of coders • May require inter-coder (rater) agreement • Requires relevant expertise (e.g. law, statistics)	• A TA team conducted a literature review to summarize the known potential effects of geomagnetic disturbances on the U.S. electric grid (GAO-19-98) • A TA team, with support from GAO's Office of the General Counsel, conducted a review of relevant case law as part of its assessment of the use of forensic algorithms in federal law enforcement (GAO-20-479SP) • A TA team conducted a regression analysis on irrigation, crop, and technology data (GAO-20-128SP)

Source: GAO-20-246G and review of GAO technology assessments. | GAO-21-347G

Examples of Methodologies for Physical Evidence

Physical evidence is obtained by direct inspection or observation of people, property, or events. The appropriateness of physical evidence depends on when, where, and how the inspection or observation was made and whether it was recorded in a manner that fairly represents the facts observed. Common considerations for physical evidence include site selection methodologies, intended analytical approaches, and resource considerations. Table 11 provides more examples.

Table 11: Select Examples of Methodologies for Physical Evidence

Level of structure	Example methods	General benefits	General limitations	Examples from GAO technology assessments (TA)
Low	• Post-visit summary of observation • Site visit • Individual photos, videos, or other recordings	• Quick generation of compelling and engaging illustrative observations	• Not generalizable • May be hard to establish reliability	• A TA team conducted site visits with developers to interview their staff and observe their facilities, including the developers' multiplex point-of-care technologies (GAO-17-347)
High	• Case study • Ethnographic methods (such as field studies, participant observation, and tester audits)	• Multiple sources of information can be used to help compare, contrast, and combine different perspectives of the same process, increasing reliability and validity of findings • Qualitative, rich descriptions of behavior and in-depth information about a topic • Often used to answer complex "how" and "why" questions • Typically qualitative, but could include quantitative data	• Small number of cases may prohibit generalizability • Training of observers of testers may be necessary • Reduction of voluminous qualitative data can be difficult • May be difficult to develop appropriate scripts, questions, and data collection instruments	• A TA team conducted case studies of six states to identify and assess different approaches to address risks associated with wildland fire, interoperability of communications, or use of military resources (GAO-05-380)

Source: GAO-20-246G and review of GAO technology assessments. | GAO-21-347G.

In addition to physical evidence, GAO may also rely on data compiled from other, secondary sources. Considerations for those secondary data are dependent on the type, source, and collection method, and could include all of the considerations above. Use of secondary data is usually more efficient than collecting new data on a topic, and administrative records (a form of documentary evidence) are generally not as prone to self-reporting biases that may be present in testimonial evidence. However, when secondary data are used, more work may be required to assess whether data are reliable and appropriate for a given purpose. For example, analysts will gather all appropriate documentation, including record layout, data element dictionaries, user's guides, and data maintenance procedures. Depending on the database, procedures and analysis can be very complex—and it would be important to note assumptions, limitations, and caveats pertaining to the data, which may affect the conclusions that can be drawn based on the analyses.

Examples of Analytical Approaches

Examples of methods and analytical approaches found in the literature and GAO reports include:

- Interpretive structural modeling: shows a graphical relationship among all elements to aid in structuring a complex issue area, and may be helpful in delineating scope.
- Trend extrapolation: a family of techniques to project time-series data using specific rules, and may be helpful in forecasting technology.
- Scenarios: a composite description of possible future states incorporating a number of characteristics, and may be helpful in policy analysis.
- Scanning methods, such as checklists: listing factors to consider in a particular area of inquiry, and may be helpful in identifying potential impacts.
- Tracing methods, such as relevance trees: includes identifying sequential chains of cause and effect or other relationships, and may be helpful in identifying potential impacts.
- Cross-effect matrices: two-dimensional matrix representations to show the interaction between two sets of elements, and may be helpful in analyzing consequences of policy options.

- Simulation models: a simplified representation of a real system used to explain dynamic relationships of the system, and may be helpful in identifying impacts and forecasting technology.
- Benefit-cost analysis: a systematic quantitative method of assessing the desirability of government projects or policies when it is important to take a long view of future effects and a broad view of possible side effects.
- Decision analysis: an aid to compare alternatives by weighing the probabilities of occurrences and the magnitudes of their impacts, and may be helpful in determining impacts and assessing policy options.
- Scaling: an aid that may include developing a matrix that identifies potential impact related to an activity and stakeholder group, and qualitatively or quantitatively assesses the potential impact, and may be helpful analyzing potential impacts, including of policy options.
- Meta-analysis: an analytic approach used to produce quantitative estimates of the size and direction of some effect using existing studies.
- Roadmapping: used to portray the structural relationships among, for example, science, technology, and applications; and employed as a decision aid to identify gaps and opportunities in science and technology programs and improve coordination of activities and resources.

Appendix V: Overview of Scope and Design of Policy Options for Technology Assessments

This appendix includes information on policy options that is presented in the chapters of this handbook and highlights stages for sound design of policy options. To ensure that the information and analyses meet policymakers' needs, it is particularly useful to outline the stages involved in sound design, while remaining aware of the iterative and nonlinear process and that the development of policy options is very context- and TA-specific.

Background

GAO includes policy options in some of its products to further assist policymakers in addressing the effects of a technology. GAO defines policy options as a set of alternatives or menu of options that policymakers could take that may enhance benefits or mitigate challenges.[44] Policymakers may include legislative bodies, government agencies, standards-setting organizations, industry, and other groups. As with all GAO products, GAO's quality standards and standards of evidence apply, including to technology assessments (TA) that present policy options. TAs meet GAO's rigorous quality standards that are designed to assure that all GAO products provide accurate, credible, and balanced information.

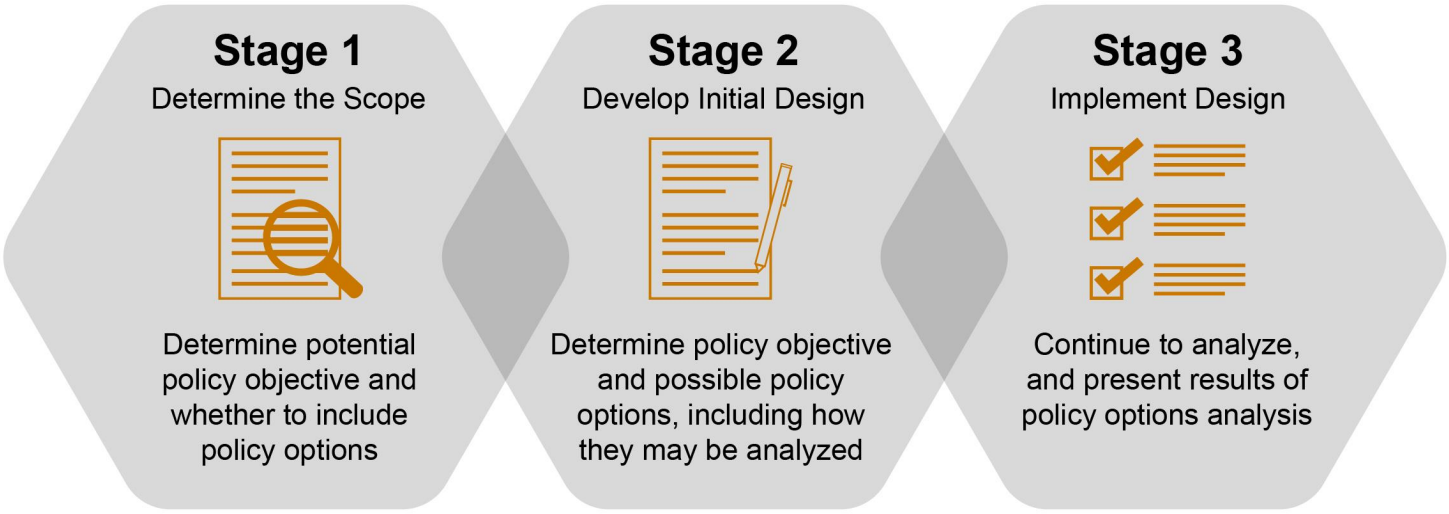
Stages for Design of Policy Options for Technology Assessments

Figure 2 outlines stages related to the design of policy options for TAs, within the overall design of TAs (refer to Figure 1). While Figure 2 presents the design of policy options as a series of stages, actual

[44]Policy options are for policymakers to consider and take action on at their discretion. In addition, GAO TAs strive to list likely policy options supported by analysis, but the list may not be exhaustive, and policymakers may choose to consider other policy options not listed by GAO.

execution is highly iterative and nonlinear. In addition, it is critical that teams begin this process early and engage with stakeholders. Furthermore, teams need to be prepared to re-visit design decisions as information is gathered or circumstances change.[45]

Figure 2: Summary of Key Stages for Design of Policy Options for Technology Assessments



Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

Text of Figure 2: Summary of Key Stages for Design of Policy Options for Technology Assessments

Stage 1: Determine the Scope

Determine potential policy objective and whether to include policy options

Stage 2: Develop Initial Design

Determine policy objective and possible policy options, including how they may be analyzed

Stage 3: Implement Design

Continue to analyze, and present results of policy options analysis

Source: GAO-20-246G and review of GAO experiences and external comments. | GAO-21-347G

[45]Refer to Appendix III for a summary of the typical GAO engagement process, of which design is a part. Also, refer to Appendix IV for example methods.

Stage 1: Determine the Scope

During stage 1, TA teams will make scoping decisions that are informed by an initial situation analysis.[46] Teams may use the situation analysis, along with congressional request, evidence, and other factors to identify and develop a possible policy objective, which will also help determine whether policy options may be part of the scope. Teams will need to ensure that the policy objective is balanced (is not biased for or against any potential course of action). The policy objective serves to guide the development of policy options by stating their overall aims and helping to identify the landscape and scope of policy options.

Scoping decisions ultimately affect the conclusions a TA can draw, as well as the policy objective and options it can consider. Therefore, teams should document areas that have been scoped out, along with any key decisions, limitations, and considerations that provide context to the conclusions.

Stage 2: Develop Initial Design

During stage 2, TA teams continue to build on the situation analysis work from stage 1 and gather more background information, and:

- Refine the policy objective
- Identify the possible policy options that will be considered
- Describe how possible policy options may be analyzed, including relevant dimensions of analysis

TA teams may develop a list of possible policy options based on an initial literature search, initial discussion with experts, and other factors.[47] TA teams may also find it necessary at this stage to initially group policy options, such as by similar themes, or eliminate some options as being beyond the scope of the TA.[48] TA teams will need to think about whether the possible policy options are appropriate to the size and scope of the

[46]An initial situation analysis may entail a preliminary literature search, early interviews with experts, review of relevant GAO bodies of work, among other methods. Please refer to Appendix IV for additional information regarding methods.

[47]These possible policy options may evolve over time, as teams collect more evidence and perform further analysis.

[48]Themes for grouping of policy options may include: subject matter, type of policy, or phase of technology.

TA, as well as whether they are in line with the policy objective and the overall TA purpose. In keeping with the iterative nature of TA design and execution, any policy option list will be revisited, modified, or refined, as needed, as the work progresses and more information is gained. TA teams may also need to plan to include policy analysis and exploration of the ramifications of each policy option during subsequent design and implementation stages.

Furthermore, if policy options are being considered, it is important to determine the relevant dimensions along which to analyze the options. The dimensions will be highly context-specific, vary from TA to TA, and depend on the scope and policy objective of the TA. Dimensions for analyzing policy options and analyzing evidence may include: relevance to the policy objective, stakeholder impacts, cost/feasibility, legal implications, magnitude of impact, ease of implementation, time frames, degree of uncertainty, and potential for unintended consequences.

Stage 3: Implement Design

During stage 3, it is important to consider changes in the operating context—such as changes in the operating environment, understanding of the issues, and access to information—and review and make changes to the design and project plan accordingly. For example, if a policy options list was developed earlier in design, it may be necessary to revisit the list as work progresses. In addition, TA teams may gather additional information regarding the policy options, further analyze policy options, and present the results of the analysis. Teams should present policy options in a balanced way, including presentation of opportunities and considerations, and not resulting in a single overall ranking of policy options.

Appendix VI: GAO Contact and Staff Acknowledgments

GAO contact

Timothy M. Persons at (202) 512-6888 or PersonsT@gao.gov and Karen L. Howard at (202) 512-6888 or HowardK@GAO.gov.

Staff Acknowledgments

In addition to the contacts named above, key contributors to this report were R. Scott Fletcher (Assistant Director), Jane Eyre (Analyst-in-Charge), Diantha Garms (Analyst-in-Charge), Nora Adkins, David Blanding, Jr., Colleen Candrl, Virginia Chanley, Robert Cramer, David Dornisch, John De Ferrari, Tom Lombardi, Dennis Mayo, Anika McMillon, SaraAnn Moessbauer, Amanda Postiglione, Steven Putansu, Oliver Richard, Meg Tulloch, Ronald Schwenn, Ben Shouse, Amber Sinclair, Ardith Spence, Andrew Stavisky, David C. Trimble, and Edith Yuh.

GAO's Mission

The Government Accountability Office, the audit, evaluation, and investigative arm of Congress, exists to support Congress in meeting its constitutional responsibilities and to help improve the performance and accountability of the federal government for the American people. GAO examines the use of public funds; evaluates federal programs and policies; and provides analyses, recommendations, and other assistance to help Congress make informed oversight, policy, and funding decisions. GAO's commitment to good government is reflected in its core values of accountability, integrity, and reliability.

Obtaining Copies of GAO Reports and Testimony

The fastest and easiest way to obtain copies of GAO documents at no cost is through our website. Each weekday afternoon, GAO posts on its website newly released reports, testimony, and correspondence. You can also subscribe to GAO's email updates to receive notification of newly posted products.

Order by Phone

The price of each GAO publication reflects GAO's actual cost of production and distribution and depends on the number of pages in the publication and whether the publication is printed in color or black and white. Pricing and ordering information is posted on GAO's website, https://www.gao.gov/ordering.htm.

Place orders by calling (202) 512-6000, toll free (866) 801-7077, or TDD (202) 512-2537.

Orders may be paid for using American Express, Discover Card, MasterCard, Visa, check, or money order. Call for additional information.

Connect with GAO

Connect with GAO on Facebook, Flickr, Twitter, and YouTube.
Subscribe to our RSS Feeds or Email Updates. Listen to our Podcasts.
Visit GAO on the web at https://www.gao.gov.

To Report Fraud, Waste, and Abuse in Federal Programs

Contact FraudNet:

Website: https://www.gao.gov/fraudnet/fraudnet.htm

Automated answering system: (800) 424-5454 or (202) 512-7700

Congressional Relations

Orice Williams Brown, Managing Director, WilliamsO@gao.gov, (202) 512-4400,
U.S. Government Accountability Office, 441 G Street NW, Room 7125,
Washington, DC 20548

Public Affairs

Chuck Young, Managing Director, youngc1@gao.gov, (202) 512-4800
U.S. Government Accountability Office, 441 G Street NW, Room 7149
Washington, DC 20548

Strategic Planning and External Liaison

Stephen J. Sanford, Acting Managing Director, spel@gao.gov, (202) 512-4707
U.S. Government Accountability Office, 441 G Street NW, Room 7814,
Washington, DC 20548

Please Print on Recycled Paper.