U.S. Department of Transportation
Federal Highway Administration

TEACR Engineering Assessment

Adaptation Decision-Making Assessment Process (ADAP)

Introduction

The Adaptation Decision-Making Assessment Process (ADAP) is proposed as a tool for planners and designers to account for the increasing role of climate change in the design of civil works projects. ADAP is intended as a risk-based tool to aid decision makers in determining which project alternative makes the most sense in terms of life cycle cost, resilience, regulatory and political settings, etc. ADAP provides a framework for generating the information needed to identify preferred approaches to project design based upon costs and benefits. The process can be tailored to meet an agency's specific requirements. Although the framework lays out specific steps, unique situations may warrant adjustments within the general confines of the framework.

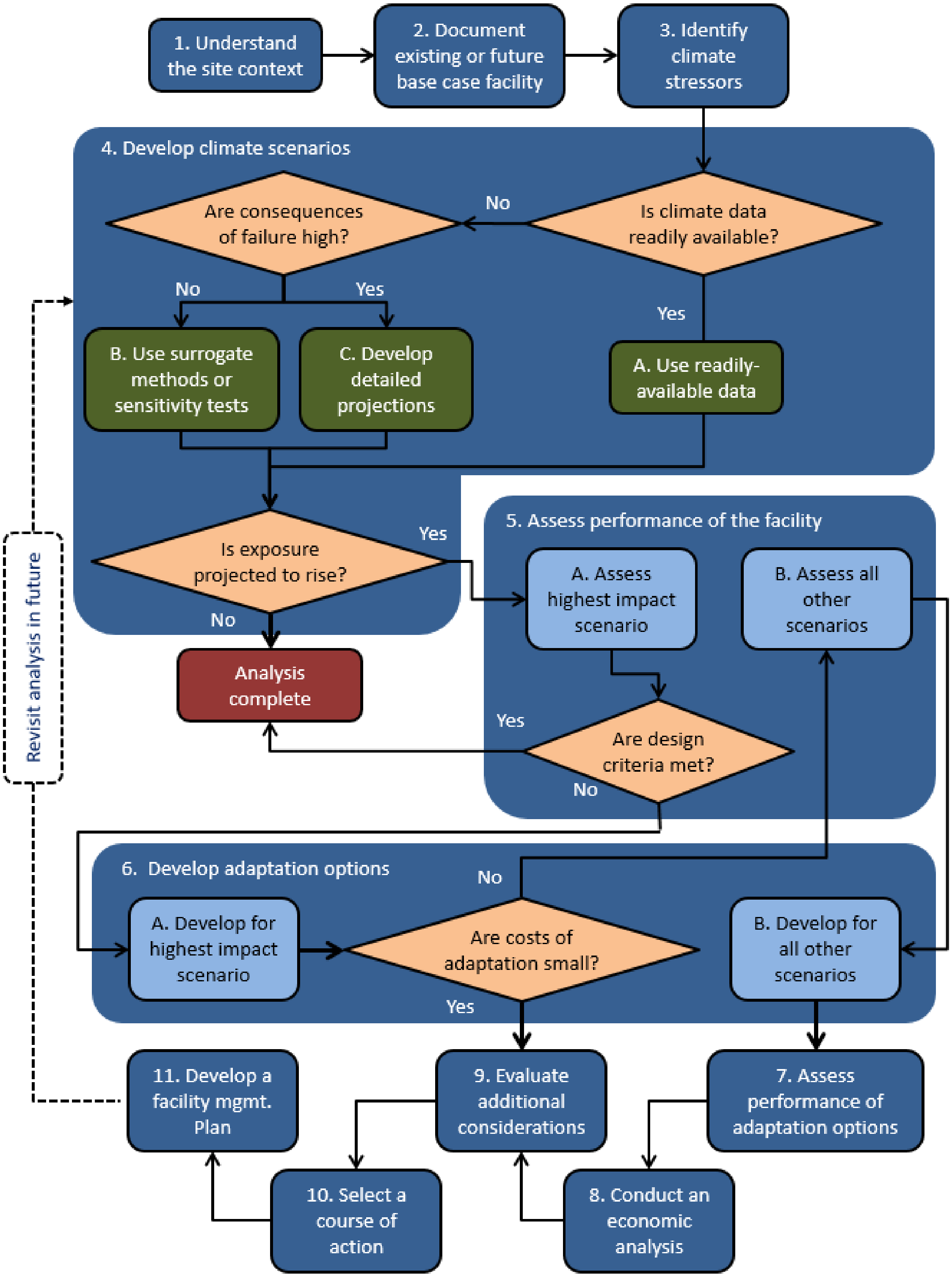
ADAP can be used in two ways: (1) to assess existing assets for their sensitivity to projected climate changes and (2) for the design of new infrastructure projects. For new projects, it is intended to be applied during the planning stage of project development so as to provide the maximum opportunity to explore project alternatives.

ADAP was also designed to be general enough to apply to the entire spectrum of climate-influenced highway infrastructure, from a small drainage culvert on a country road to a complex bridge in a major urban area. Determining which facilities/projects ADAP should be applied to will be a policy decision made by each agency. Agencies may choose to apply ADAP to existing or new projects. Some agencies may use ADAP for all projects, while others use it only when projects meet certain criteria related to cost, importance, potential vulnerability, etc. ADAP may not be the ideal process to follow in all situations; however, it lays out the range of considerations that should inform an agency's thinking about climate change vulnerability and adaptation options.

Finally, ADAP is designed from the perspective of assessing a single asset, but it could be easily adapted to consider more system-level considerations, such as a system of culverts within a watershed. The language in this document assumes that a single asset is being evaluated. If a system approach is taken, then the same ADAP steps should also be followed, but adjusted as needed to account for system-level considerations.

The ADAP steps are captured in the decision tree in Figure 1. As can be seen, not all steps are required in all situations. The process is setup to minimize the evaluation process in situations where the consequences of asset failure are low and where the cost of adapting to climate change is relatively small. The steps are explained in more detail in the following sections.

Figure 1: Decision Tree of the ADAP Steps



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Step 1: Understand the Site Context

Understanding the context of a facility is a critical step in setting up a proper assessment. The context to be considered includes both the facility's function within the broader transportation network and its location within the natural environment. These considerations include the long-term functional life of a facility given projected climate impacts on land uses served by the facility. Step 1 should involve coordination with other government agencies on their adaptation strategies.

Step 2: Document Existing or Future Base Case Facility

For existing facilities, this step involves documenting and understanding the dimensions, design criteria, and remaining design life of the existing facility being studied. For proposed facilities, this step entails understanding appropriate design and design standards for the project based on current, observed climate data. Although a full design for the asset may not be necessary, this step should involve sufficient understanding of the potential design to be able to evaluate whether adaptation is cost-effective.

Step 3: Identify Climate Stressors

This step involves documenting the climate stressors (e.g. precipitation, temperature, storm surge, wave heights, etc.) that affect the design of the facility. Some facilities might be affected by multiple or compounding climate stressors; each of these stressors should be noted and considered in the analysis.[1] Near coastal areas, practitioners should be careful to consider possible impacts from sea level rise amplified by higher storm surges, even in areas not currently affected by these stressors. Sea level rise could also interact with precipitation runoff, which may be an important compounding effect to consider. Impacts to the natural environment caused by changes in climate stressors (e.g. loss of forest cover due to conditions brought on by climate change) may also warrant consideration to the extent that they could impact the facility.

Step 4: Develop Climate Scenarios

Scenarios represent different storylines on how climate could change over the design life of the facility. They should be developed such that they capture the range of uncertainty in future climate projections. Any number of scenarios can be generated for use in the analysis; however, in most cases two to three scenarios (e.g. "high", "medium", and "low" change) are proposed as

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[1] Some analysts may choose to look at only the predominant climate stressor whereas others may choose to look at the full range of climate stressors that could affect a facility. Looking at the full spectrum of climate stressors is most important when interactions are possible amongst the impacts.

the minimum to provide an understanding of future changes without making the analysis too unwieldy.

In cases where a facility is being evaluated for the combined effects of multiple climate variables, it may be useful to maintain consistency in assumptions and modeling approaches when developing the climate projections. Maintaining such consistency may mean that more moderate values for some climate variables are selected. However, it is important to remember that it may not be appropriate to simply choose the "worst case scenario" for all variables, because it may be unlikely that the worst case will occur for all climate variables together at any given point in time.

When developing climate scenarios, decisions must also be made about which timeframes to consider. Timeframes are sometimes selected based on the expected lifetime of the asset being evaluated, but transportation agencies may wish to consider nearer term, or longer term timeframes as well.[2]

Climate projections in a format useful to highway designers are increasingly available from federal, state, and local agencies; academic institutions; non-profit groups; and private software vendors. For example, the U.S. Department of Transportation developed the *CMIP Climate Data Processing Tool*[3] to enable users to easily download and process local climate projection data for temperature and precipitation. Meanwhile, FHWA's HEC 25-Volume 2[4] presents sea level rise projections appropriate for coastal areas and includes an example using the US Army Corps of Engineer's sea level rise calculator[5]. In such cases, site specific scenarios can typically be generated with modest effort using in-house staff with some basic training in the science of climate change (Step 4A).

That said, there are still many climate variables for which there is a translation gap between what is available from climate models and what is needed by highway designers. In these cases, where the necessary climate data is not readily available, practitioners will need to determine what level

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[2] Note that, in some cases, changes in how the asset is operated over its lifetime may influence when the greatest impacts will occur. For example, in cases where there is a plan to reduce service and eventually discontinue use of an asset, the most important impacts might occur early on when climate effects are less but the service impacts are higher. In these situations, it may be more important to consider nearer-term timeframes. Alternatively, the use of some assets may persist beyond their design life so consideration of the realistic service life may be more appropriate when selecting timeframes.

[3] The CMIP Climate Data Processing Tool is available on FHWA's website at: https://www.fhwa.dot.gov/environment/climate_change/adaptation/adaptation_framework/resources/resource.cfm?resourceid=435&tagid=4.

[4] Highways in the Coastal Environment: Assessing Extreme Events: Volume 2 (HEC 25-Volume 2) is available at: https://www.fhwa.dot.gov/engineering/hydraulics/library_listing.cfm.

[5] The US Army Corps of Engineer's sea level rise calculator is available online at: http://www.corpsclimate.us/ccaceslcurves.cfm.

of effort they wish to pursue in developing the climate data. Generally speaking, the higher the dollar value of the facility being studied or the greater the consequences of its failure, the more effort should be expended in developing detailed climate projections. Higher levels of effort may involve climate modeling and the assistance of climate scientists (Step 4C) whereas sensitivity tests using possible values may be sufficient for lower levels of effort (Step 4B).

Agencies should also consider opportunities to fill climate change data gaps across broad geographies (as opposed to doing so on a project-by-project basis) so as to achieve economies of scale across many assets. When doing so, opportunities to share costs with other agencies that could make use of the data should also be explored.

After generating the climate scenarios, practitioners should assess whether the projected changes actually translate to increasing exposure for the facility relative to current conditions. If not, then adaptation will not be required and the analysis is complete.

Steps 5 & 6: Assess Performance of the Facility and Develop Adaptation Options

Steps 5 and 6 are presented together because they are not necessarily conducted in a simple linear manner. An assessment of the highest impact scenario is conducted first (under Step 5), because if the facility can withstand the highest impact scenario, it will likely be able to withstand lesser scenarios, and there is no need to develop adaptation measures under Step 6. If adaptation is necessary, but the costs of adaptation are relatively small, then it may make sense to simply adapt to the highest impact scenario under Step 6. However, if the cost of adaptation is high, then practitioners should return to Step 5 and evaluate the asset against other climate scenarios and then identify appropriate adaptation options under those scenarios, so that the most robust and cost-effective adaptation approach can be identified.

Step 5A: Assess Performance of the Facility under the Highest Impact Scenario

This step involves determining whether the existing or proposed new facility meets design criteria under the highest impact scenario. The highest impact scenario is used for an initial sensitivity test to make the process more efficient: if the facility performs adequately under the highest impact scenario, then it will likely perform adequately under all the other scenarios of lesser impact, and adaptation will not be required. In these situations, the analysis is complete and the design team should either maintain the existing facility as is (for existing assets) or build the traditional design based on historic data (for new assets). In either of these conditions, facility managers should plan to monitor facility performance as the climate changes. On the other hand, if the facility does not perform adequately under the highest impact scenario, further analysis will be required and the practitioner should proceed to Step 6A.

In defining the highest impact scenario, practitioners should be aware that the most extreme climate scenario is not always responsible for the greatest impacts on a facility. For example, with storm surge, a higher scenario that overtops a structure may actually be less damaging than a lower scenario that entails waves hitting the side of the facility for a longer time period. Also, when considering multiple climate variables affecting a single facility, one should be aware of the possibility of interactions amongst the climate variables that may amplify impacts to generate the highest-impact scenario. Thus, in a few cases, the scenario that is most impactful will not be immediately apparent and two or more scenarios may need to be evaluated to determine which causes the greatest harm to the asset.

Step 6A: Develop Adaptation Options for Highest Impact Scenario

This step is a continuation of the process from Step 5A. Under this step, the practitioner should develop adaptation option(s) that enable the facility to meet design criteria under the highest impact scenario. Practitioners should be cognizant of the range of possible actions when developing adaptation options. These potential actions include design options with flexibility built in so that designs can be readily altered as conditions warrant, as well as the use of climate-variable based thresholds that trigger specific actions in the future when reached.

When multiple climate variables are being tested for a single asset, decisions need to be made about which scenarios to use for each variable. One option is to use the highest impact scenario for each variable; for example, using the highest sea level rise scenario along with the highest storm surge scenario—even if this combined scenario is considered to be on the extreme end of what could occur. Doing so would represent a more conservative design. Some people may find such assumptions to be overly conservative, however, and may opt to use more moderate scenarios for both variables.

Cost estimates for each adaptation option should then be developed. If it is found that adapting to the highest impact scenario entails only a small increase in costs,[6] then the practitioner should skip to Step 9 and forego the detailed performance and economic analyses. On the other hand, if the costs are more substantial, a full benefit-cost analysis should be undertaken to ensure a cost-effective decision is made. In this case, practitioners should loop back to Step 5B to generate information that will allow consideration of the full array of climate scenarios and adaptation options in the benefit-cost assessment.

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[6] The definition of what constitutes a small cost increase is a policy decision to be made by each agency. Practitioners should consider the costs of doing a full economic analysis relative to the benefits to be gained when making this determination. It is possible that, for some low-cost facilities, a full benefit-cost analysis may cost as much as, or even more than, simply implementation adaptation measures for the highest-impact scenario.

Step 5B: Assess Performance of the Facility under All Other Scenarios

This step involves assessing the performance of the existing or proposed new facility under each of the remaining climate scenarios through the remainder of its design life. This step should be conducted if a full economic analysis is necessary to select the appropriate adaptation option, or if additional information is desired about the other scenarios.

This step will demonstrate how the facility would perform across the range of selected scenarios, which helps bound the potential impacts that engineers should consider, and also illustrates the effect that uncertainty in the climate assumptions has on the ultimate impact. This step also provides important baseline information for the economic analysis; a reference point for determining the costs avoided through undertaking the adaptation option.

Step 6B: Develop Adaptation Options for all Other Scenarios

If Step 5B is completed, adaptation options that are appropriate for or optimized for each remaining climate scenario should be developed. Doing so will allow for the comparison of a range of different adaptation levels to determine which is most cost-effective. Cost estimates for each adaptation option should also be determined in this step.

Step 7: Assess Performance of the Adaptation Options

In this step, the performance of each adaptation option should be assessed against each climate scenario. This assessment will provide an understanding of the robustness of the strategies across the various scenarios.

In addition, economic data (climate stressor-cost functions relating the degree of facility physical damage to the magnitude of the climate stressor(s)) should be developed if needed for the economic assessment.

Step 8: Conduct an Economic Analysis

The economic analysis provides key information for decision making, the final output being an understanding of the comparative costs and benefits of each adaptation option (relative to the base case) under each climate scenario. Decision makers can use this information to select the adaptation option that performs best (i.e., most robustly) across the range of possible future climate conditions.

A variety of techniques exist for doing benefit-cost analyses including standard engineering approaches like Equivalent Uniform Annual Cost, regional impact modeling, calculus-based methods and Monte Carlo analysis. Such analyses can be undertaken with generally modest effort by an engineer or a trained economist for the more complex analyses.

The cost of the facility and various contextual factors can help determine the level of effort to expend. Generally speaking, lower cost facilities may entail greater use of assumptions regarding various economic parameters whereas more expensive facilities may call for more work to develop better estimates. Contextual factors include whether the failure of the facility may cause widespread disruptions throughout a transportation network: if so, the use of a travel demand model may be warranted to develop better estimates of the cost to the traveling public. In many cases, however, simple assessments of the cost of the additional travel time associated with the detour are likely to be sufficient. If the facility is a major freight corridor, freight modeling might be desired to help understand the consequences of failure on freight flows. For the vast majority of facilities, however, simple calculations on the cost of the additional travel time for goods associated with the detour will be more appropriate. If nearby properties are affected by effects related to the design of the asset (e.g. if an undersized culvert causes flooding of upstream properties), the cost of flood damage to these structures caused by the facility should be accounted for. In special cases where no network redundancy exists, other broader societal cost impacts tied directly to the accessibility afforded by the structure may be prudent to include (e.g. lost income from tourism on a barrier island accessible by a single bridge may be relevant to that bridge’s valuation).

Step 9: Evaluate Additional Considerations

A variety of factors beyond purely economic considerations—such as environmental permitting constraints, site context, public acceptance, and environmental justice—are important to making the right decision on a project. What might be optimal from a purely economic perspective might not be optimal for these other considerations. This step is intended to ensure these concerns are considered before settling on a course of action.

Step 10: Select a Course of Action

This step entails selecting the option that makes the most sense considering both the economic and non-economic factors. The selected option may entail a single action at one point in time, the adoption of climate variable threshold values that will trigger specific actions when crossed, or some combination of these approaches.

Step 11: Develop a Facility Management Plan

Once a course of action has been decided, a facility management plan should be developed to ensure the project continues to perform as designed. The plan would include ongoing monitoring as the climate changes and require that corrective actions be considered.

Revisit Analysis in the Future

Though not an official step in ADAP, it may be important to revisit the analysis and conclusions in the future. Thus, the ADAP diagram shows a dotted line from Step 11 going back to Step 4 (Develop Climate Scenarios). There are several reasons to revisit this analysis in the future:

- Land-use or demographic changes may change the functional use of the asset. An asset that used to be essential to the functioning of a community may become less critical if new alternate routes are built, or a more minor asset could become more critical as the community grows and develops. The relative costs and benefits of adaptation may consequently change as well.
- Climate projection data and wave/surge/flooding modeling will likely improve over time. Assumptions about how the asset will be exposed to climate change stressors could change as information improves.
- Advancements in engineering may make new adaptation measures feasible, or lower the costs of others. Therefore, the most cost-effective approach may change over time.