




3. Accuracy & Precision

In travel demand modeling, accuracy and precision are used to determine whether the model is “correct.” While there are many variables to be considered when reviewing model results, understanding how to assess accuracy and precision will lead to more confident decision-making to assist in setting policy and identifying projects for investment.

Accuracy

Accuracy refers to how close a model’s results are to actual travel conditions, determined by comparing the model’s results to observed data. Typical measures of accuracy include difference ratios such as volume-to-count and root mean squared error (RMSE). These measures are used during the model calibration and validation phase when a model is developed. Having a reasonably validated model is the first step of any project that uses travel demand models.

		
<p>Project coordinators should allow for sufficient time and budget for the modeler to assess a model’s accuracy and, if necessary, undertake the effort to improve the model’s performance. This includes having the modeler:</p> <ul style="list-style-type: none"> • Assess the validation of the model, especially within the study area. • Make recommendations on any additional validation that would be required. • Provide an estimate on what it would take to sufficiently validate the model. 	<p>As the modeler, you will be the one determining how accurate a model is. Start by assessing the base year validation of the model.</p> <ul style="list-style-type: none"> • The model’s validation report should be available from the model owner. • Chapter 4 of <i>Developing a Travel Demand Model</i> provides resources for assessing model validation. • NCHRP Report 934 discusses the complications with determining forecast accuracy in greater detail and provides guidance on how to assess forecast accuracy. 	<p>The model’s forecasts are based on the best available data, assumptions, and methodologies at the time they are made. While the accuracy of the model cannot be verified until future conditions occur, the model reliably replicates observed conditions, ensuring confidence for informed decision-making. Keep in mind that the following non-model issues can impact forecasts:</p> <ul style="list-style-type: none"> • Land use may develop in unexpected ways. • Unforeseen economic changes, such as the loss of major employers. • Transportation projects can get reprioritized.

Model Variance

Variance occurs when model results differ from observed conditions. All models contain variance because they are based on averages, and individual behaviors may be closer to or further from the average. Ideally, variance is randomly distributed in the model. If the variance is within acceptable tolerances, randomly distributed error reduces the chance that any one portion of the model contains issues that can skew forecasts.

Modeling assumptions impact variance. In addition to model-specific assumptions that compensate for missing data, models possess **core assumptions** that influence variance, including:

- Model equations are adequate representations of human behavior.
- Models are simplified representations of the world.
- Current behavior is an adequate predictor of future behavior.

A good model seeks to minimize variance but cannot eliminate it entirely.

Reasonableness

A related concept to accuracy is reasonableness. Reasonableness is a model behaving in a way that makes sense based on the understanding of how travel behavior works. For many projects, reasonableness can be more important than accuracy. This is true for projects that measure relative impacts from competing alternatives. Reasonableness is measured through sensitivity testing. Testing sensitivity is changing the model's inputs to determine if the model reacts in a reasonable way.



Sensitivity testing can identify the usefulness of a model for a given purpose by showing what happens to the model's outputs when the model inputs are changed. If there are concerns about a model's suitability due to accuracy, recommend sensitivity testing as part of the approach. Test runs can include:

- Increasing or decreasing the population to see the impacts to the number of trips.
- Artificially increasing or decreasing the speeds or capacities on certain roads to see how routing changes.
- Altering the accessibility to transit stops to observe the impacts on mode share.

Results should be intuitive. Unexpected results to these tests can point to underlying issues with the model that will need to be addressed.



As an example of variance, consider a household survey that indicates that households in a region make an average of 10 trips per day. In reality, households will make fewer or more trips than that depending on the makeup and needs of each household. This difference between what individual households actually do and the average behavior that the model represents is the variance. So long as these differences are randomly distributed across the modeled region, the model overall remains balanced. Keep in mind that despite being regionally balanced, it is possible that the variance in the project study-area is too great and further refinement of the model may be required.

Overfitting

Achieving too high a level of model accuracy to observed conditions can result in over-fitting. Models need to be representative of observed conditions while also being flexible enough to measure changes in travel demand resulting from alternative transportation network and land use conditions. Over-fitting makes the model too uniquely suited to the observed condition. The model becomes useless because it cannot represent any other situation. It is reasonable to expect some variance. Variance that is too low or non-existent is unreasonable and will need review and adjustment. An overfit model will not be able to provide meaningful information about different scenarios. Models need to be sufficiently sensitive to test various scenarios and alternatives.

Precision

Precision refers to the degree of refinement of a model's results, such as whether there is the right level of information. Considering things like how many decimal places are needed in data and whether link volumes versus segment volumes should be used helps to fine-tune precision. A model's precision is significant because meaningful decisions rely on differences measured from a model's results.



When regional model validation achieves %RMSE below 25 percent, it could be an indication that the model is overfit. Validations with %RMSE below 20 percent are not expected and should be assessed for brute force calibration techniques that will result in an insensitive model. Some things to look for include:

- Targeted speed adjustments on specific links inconsistent with the rest of the network.
- Unnecessary or exaggerated turn penalties or prohibitors.
- Unreasonable centroid connector placement such as at intersections.
- Trip distribution and mode choice parameters with unexpected or exaggerated values.



When meeting with stakeholders, be sure to ask about their precision needs. Many stakeholders will not think about precision in scientific terms. Your questions should focus on understanding what questions they need answered so that you can work with the modeler to ensure that the model provides the necessary level of detail.

Impacts Precision

- Number of lanes.
- Number of trips.
- Amount of revenue.
- Units of measure (gallons, grams, etc.)
- Amount of congestion.

Spatial/Temporal Precision

- Jurisdictional boundaries.
- Study area definition.
- Study corridor definition.
- Daily/time-of-day/hourly.

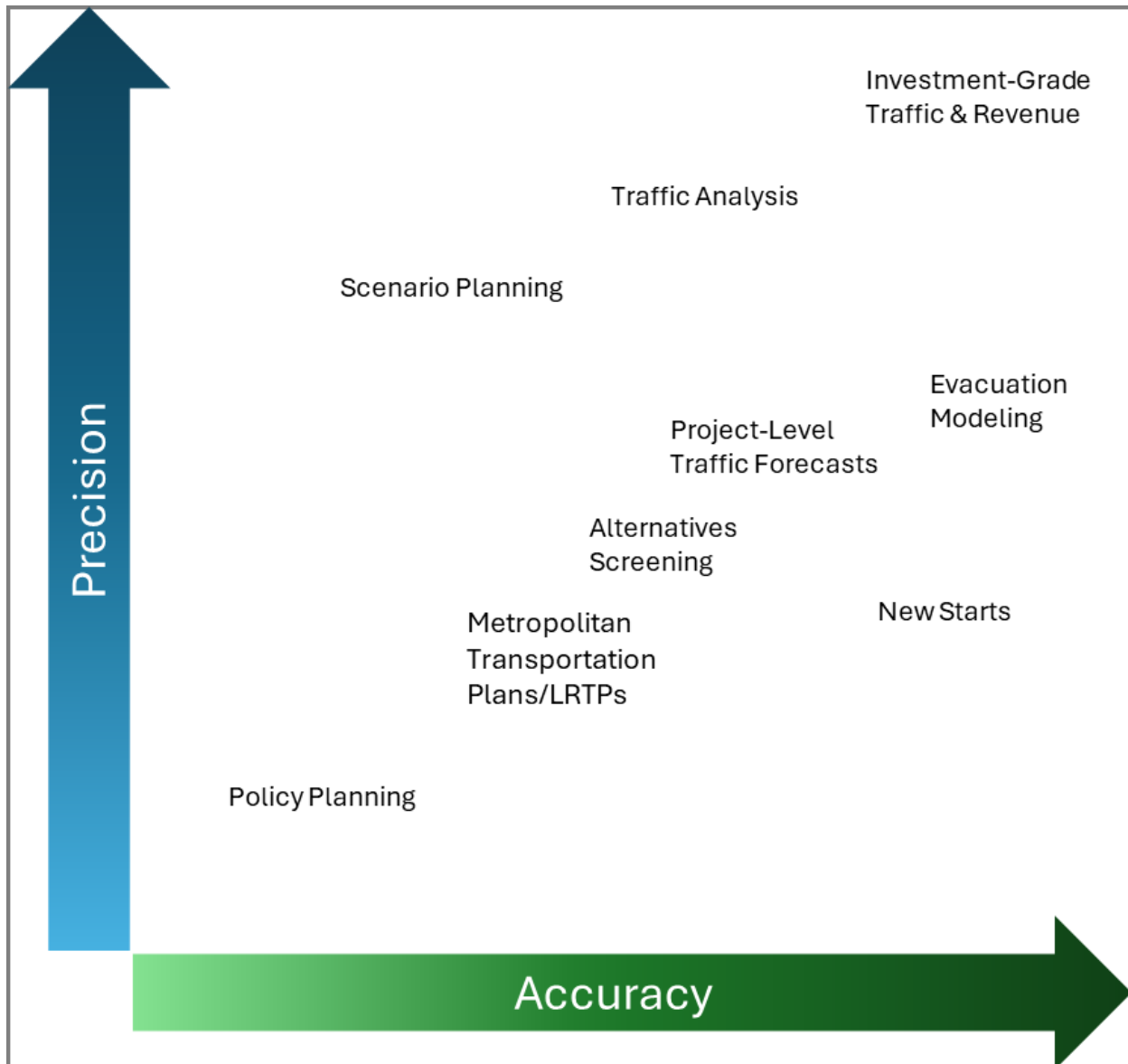
Mathematical Precision

- How many decimals?
- Round to the nearest...?
- Ratios and percentages.

Accuracy & Precision in Practice

When considering the level of accuracy and precision needed in a model, users of the model, uses of the model, and the needs of stakeholders should be considered. The level of accuracy and precision required of a model depends on the types of decisions being supported by the model. Typical uses and the relative level of accuracy and precision generally required are shown in Figure 1.

Figure 1 Accuracy and Precision Relative to Model Use



Assessing Accuracy and Precision



Considering how the model will be used is needed for adjustments to fine-tune accuracy and precision. Review the available model and consider the following early in the process:

- **Model's base year validation.** When models are developed, a base year validation is conducted to establish the model's accuracy with respect to observed data. Questions to consider:
 - In addition to the model, what are the specific corridors and areas being studied?
 - Do any areas of the model appear to be outside of accepted validation ranges?
 - What is the model's volume-over-count and percent-RMSE?
- **Model's level of detail in the study area.** Travel demand models are developed to deal with aggregate data, meaning that a model may or may not have the proper detail for a particular study. Questions to consider:
 - Are the roads and intersections required for the study included in the network?
 - Do the model TAZs support the network system required for the study?
 - Given the granularity of the input data available, can the model replicate the appropriate period of time (known as temporal resolution)?
 - » For instance, daily / peak-period / peak-hour.
 - Does the model include the desired horizon year? Interim years?
- **Potential need to enhance the model.** Models that are not sufficiently validated and / or have an insufficient level of detail in the study area may have accuracy issues. Questions to consider given the study area:
 - What are the potential issues that can impact the model's accuracy? Develop a plan to compensate for these issues.
 - Are model enhancements necessary to produce reasonable model results? The need to enhance the model should become apparent when reviewing potential issues.

After assessing the model for accuracy and precision for your project, communicate your findings to the project coordinator. Be prepared to:

- Recommend a course of action to address issues or concern.
- Provide an estimate on the level-of-effort to implement your recommendations.
- Suggest an alternative approach if the level of effort is too great.
- State if there is no viable alternative to enhancing the model. This could have greater implications for the project as a whole.

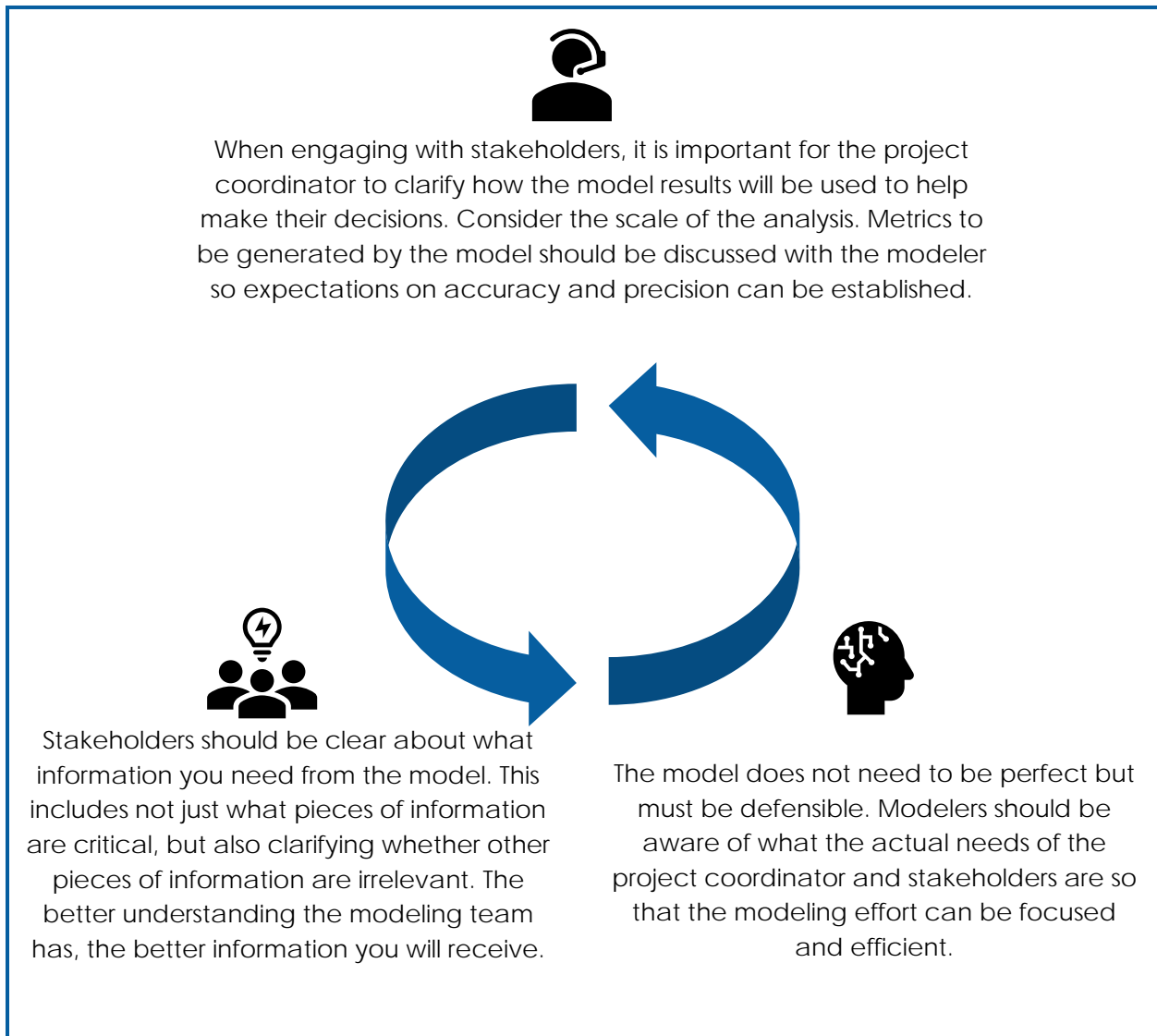
Improving Accuracy and Diminishing Returns



Initial improvements to accuracy may be dramatic, especially if the variance is high; however, as the model continues to be improved, gains in accuracy become marginal. It is necessary to understand the level of accuracy required for a given project to keep budgets and schedules reasonable.

Accuracy and Precision Thresholds for Decision Support

Models only need to be as accurate and precise as necessary to support the decision-making process. Making a model too accurate can result in wasted effort and resources to improve a model that was already well-suited to support the project. Making a model too precise can mislead decision-makers into thinking that irrelevant differences in results are important enough to base a decision on.





Project coordinators should determine the level of accuracy needed for the project's success. The goal is to have a reasonable approach to decision-making depending on the decisions being made:

- Policy and programming decisions are usually concerned with metrics at the regional and larger scale.
- Design decisions are usually concerned with the corridor and intersection scale.
- Planning and prioritization can be at a higher level or be more detailed depending on the need.

When discussing the approach with modelers, the project coordinator should keep in mind the following:

- Are there relevant statutes, regulations, or guidelines that explicitly identify metrics and criteria to be used in the process?
 - Is there a need for criteria not currently covered by existing statutes, guidelines, or regulations?
- Model variance is only significant to the extent that the variance impacts the decisions being made. How will model variance affect project outcomes?
- Relevant variance can be determined by considering how the outputs of the model need to be presented, including:
 - Knowing the study area being analyzed.
 - Understanding the level of precision/rounding that is required for quantitative outputs.
 - Determining whether metrics need to be given in absolute values (such as determining when an alternative meets a certain threshold) or in relative values (such as determining if one alternative performs better than another).
- Are funds available to enhance the model's accuracy?
- What are the opportunity costs for adjusting the model?
 - Time and money spent on adjusting the model may take away from other activities.
 - Project schedule may be delayed by adjusting the model, potentially impacting project deadlines.
- Are project deadlines mandated by external factors (such as grant application deadlines, project letting schedules, or regulatory deadlines) that would impact timing for enhancing the model's accuracy?
- If extensive adjustments are needed, should a separate scope be developed to accommodate the adjustments required?

Model Replication

Prior to making any adjustments to the model or developing any scenarios, model replication should be established as per the outline to the right. Model replication is used to guarantee that the correct version of the model is being used for a project and that the model has been set up and executed correctly by the modeler.

A detailed model replication procedure is provided below. To accomplish replication, follow this procedure.



Model Replication

1. Request official model outputs from model owner if not already provided.
2. Set up model on modeling computer.
3. Run base year scenario.
4. Confirm model ran correctly.
5. Compare results and confirm results match.
6. If results do not match, review model setup and look for errors. Retry replication until match achieved.
7. If results match, document replication.
8. Inform project coordinator that model adjustment and scenario modeling is ready to proceed.



Pre-Modeling

1. Determine the version of the model to run.

The version of the model to be used for the project should have been determined ahead of time, usually during scope development or in pre-scoping meetings. The model to be used is often the most recent version of the regional model developed and published by the model owner.

2. Ensure that the model software is the right version.

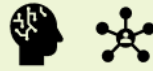
Models are developed using specific modeling software and will require a specific version of a specific software to run properly. The model owner can identify the proper software version to use for running a model.

3. Check if the hardware available is adequate to run the model.

Complex models may require computers with precise hardware specifications to execute properly. Hardware requirements should be available with a model's documentation. If this is not the case, this information should be available through the model owner. This is also the time to determine if multiple computers will be required for the project. This may be necessary if the modeler will be modeling many scenarios.

4. Acquire, install, and set up the model.

The most recent version of one of Florida's regional/districtwide models can be downloaded from the following link: [Models \(fdot.gov\)](https://www.floridadot.com/models). Once acquired, the model should be installed on the computer(s) used to run the project model. The installation process should be included in the model's documentation. If this is not the case, the model owner should be able to provide this information. Advanced model users may have network-based solutions to install and run a model, but this is typically not recommended unless the modeler has significant experience with such setups.



Modeling

5. Run the model base year.

Assuming the model has been validated, it is a reasonable assumption that the model base year will run completely and without fatal errors. The modeler should run the base year and ensure the model runs completely from beginning to end.

6. Check the model for error messages.

The modeler should ensure that the model ran completely and without crashing. Modeling software typically makes use of error codes to indicate a crash. The modeler should possess enough familiarity with the software to correctly determine whether the model ran to completion or crashed. **If the model crashed, the modeler would need to determine why the crash occurred and correct it before the project can proceed.**

7. Check assignment results and compare them to an existing base year run.

The model owner should have an available set of archived base year model outputs. If these were not provided with the model, they should be requested. If the base year model outputs were not archived, the modeler should request that the model owner recreate the outputs. **It is important that the modeler attempting to achieve model replication is not the one to recreate the original model outputs.** A deterministic model should always yield the same results each time the model is run under similar conditions. This is determined by comparing assignment results.

8. If assignment results differ from the existing base year run, check each step of model outputs.

If assignment results are not the same, it is necessary to determine the source of the error by checking model results against the existing base year model run step-by-step and working backward from assignment. The step where the model results first diverge is where the error is occurring. Recheck to make sure that the instructions provided with the model were followed correctly. Correct any mistakes discovered. If no mistakes in model installation and set-up are discovered, discuss the issue with the model owner. If necessary, hold a meeting with the model owner and project coordinator to determine a path forward if replication cannot be achieved.

9. If using multiple computers for a study, ensure replication on all machines.

This will ensure that any differences in model results between scenarios modeled on different computers are due only to the differences in scenario inputs and not due to an error in how the models were installed and executed on the different machines.



Post-Modeling

10. Replication is achieved when model outputs on all project computers are the same as each other.

Document the finding of replication and communicate this finding to the project coordinator. The modeling of the baseline can now proceed.

Fit for Purpose

After model replication has been achieved, any adjustments to the model that are required to make it fit for purpose can be undertaken. A model is fit for purpose when the accuracy and precision concerns discussed earlier in this chapter have been addressed. To make a model fit for purpose, consider the following work items which the modeler should incorporate in the approach presented to the project coordinator:

- Network refinement:
 - Include additional roads/local streets.
 - Improve ramp and interchange details.
 - Correct errors in network coding.
- TAZ refinement:
 - Split TAZs.
 - Adjust TAZ boundaries.
 - Update socioeconomic data.
- Subarea validation.
- Additional post-processors and data analysis tools to process model outputs.
- Development of new model components/additional features/scripts.



A review of the model results in the study area will determine if the model is suitably validated in the study area. This can be determined by analyzing the model's performance in the study area from the model validation. Additional observed data for the study area can be helpful if TAZ splits and additional network detail are part of the approach. Subarea validation is warranted if the validation of the model in the base year indicates that as a subarea of the model, the study area is performing outside of the accepted standards and guidelines for model validation. Subarea validation may also be warranted if the model's performance in the study area falls outside of the expectations for model accuracy, as discussed during the scoping process.

The adjustments made to the model to make it fit for purpose should not rise to the level of warranting a revalidation of the model at the regional level. Adjustments made to the model should be tested to determine if the regional validation was negatively impacted, but this should not require a completely new validation effort as described in Chapter 4 of Developing a Travel Demand Model. If there is a concern that the nature of the adjustments would require a revalidation of the model at a regional level, then it is likely that the proposed adjustments are too excessive.