Optimization Analysis Options

Optimization analysis is a powerful analysis tool where the inputs to each analysis and results from each analysis are retained for future review, use in planning, and use in creating new optimization analyses. The following types of optimization analysis are available:

- Estimate Based on Plan
- Multi-constraint Optimization
- Multi-year
- Multi-year with Work Plan
- Prioritization
- Ranking
- Worst-first Ranking

Estimate Based on Plan Analysis

The Estimate Based on Plan type of analysis employs only a user-defined master work plan (MWP) as the work plan in future years. It employs deterioration and improvement in the same manner as all other analysis types. The result of this analysis is to show the resultant condition of the network in future years if only the MWP is employed.

Multi-constraint Optimization Analysis

In multi-constraint optimization analysis, the initial characteristics for all road sections come from the Network Master table. It then uses an integer programming optimization engine to simulate future years to either: maximize a benefit or condition estimate for given rehabilitation cost goals; or minimize rehabilitation costs for given condition goals.

For each year in the analysis period, a sequence of steps occurs:

1. Before the optimization analysis is run, all road sections have their conditions deteriorated by a year.
2. Use the decision trees to assign possible treatments.
3. The optimization engine is then applied independently of each year of the analysis period.
4. At the end of the year, after optimization is run, the road sections that have been rehabilitated have their conditions improved accordingly.

Constraints and Objective Function

Each optimization analysis has one objective, which is essentially the goal of the optimization analysis. Each analysis also has one or more constraints. These serve as the mechanism to halt analysis during a particular year of the analysis period. Optionally, you can also configure different constraint levels, either per year or per additional user-defined “segregating” variables such as functional class and district. A wide variety of constraint and segregating variables are available, and they can all be configured from within an AgileAssets application (for example, via the PMS Columns Used in Analysis and Setup Constraint Subdivisions windows).

All constraint variables as well as the objective can be aggregated by one of the following methods: percentage above threshold; total; or weighted average. Condition variables are typically aggregated as weighted average or percentage above threshold; the Benefit variable must be aggregated as weighted average; and the Cost variable must be aggregated as a total.

The following objective functions are available in multi-constraint optimization:

- Minimize treatment cost
- Maximize condition (Benefit, RSL, or Performance Indices)
- Maximize the percentage of the network above a given threshold (RSL > x or Performance Index > x)

Decision Trees

In multi-constraint analysis rehabilitation decision trees are applied each year to all road sections in the network. The recommendations are inputs to the optimization engine, which selects the best set of recommendations that conform to the constraints.

For each optimization analysis you select the decision tree set to employ. Two types of decision tree sets are available: General (single treatment selection) and INCBEN (multiple treatment candidates). The differences between General and INCBEN decision tree sets are described below:

- General Decision Tree Sets: For a General decision tree set, several lower-level decision trees can be assigned to the upper-level portion of the decision tree. The lower-level decision trees can have only one treatment assigned per limb. During analysis, then, a road section can have a treatment recommended for each lower-level decision tree that is bundled together. The final single recommended treatment is the one with the highest treatment priority.
The multi-year analysis method uses the same components as associated with each section. Once the system estimates improvements, the consequent changes in deterioration rates must also be assigned by changing the assigned model step.)

improvement. In addition, any other columns that are identified as changing due to the application of a treatment are also modified during this case, a treatment is assigned to each section in this year. For each treatment, a performance index improvement is set for all defined deterioration types as configured in the Setup Treatments window. Graphically, these types are represented as follows:

- Improvement with No Model Change: This model only changes the current condition of the pavement for the index. The next time the system calculates deterioration it will use the same model equation as used in the previous deterioration cycle. The system will apply a section model to the pavement if one exists; otherwise, it will use the appropriate Performance Class model.
- Improvement with Model Change: This deterioration type discards any current section model. Then, during the next deterioration cycle, the system chooses a new model from the available performance class models.
- Increase Index RSL by N Years: This deterioration type modifies the deterioration of the pavement by slowing its deterioration rate. The method used to apply this function ages the pavement only a reduced amount per year. The reduced age factor is determined by dividing the original RSL for the untreated section by the increased RSL.
- Improvement Deteriorates in N years: This deterioration model is normally applied for treatments that have a temporary effect on pavement condition. After application, the pavement's condition improves, but it then deteriorates at a faster rate over the effective life of the treatment. The amount of accelerated deterioration is determined by dividing the Improvement by the number of effective years. During the deterioration cycle the system deteriorates the pavement according to the original model for one year plus the additional, accelerated deterioration.

Deterioration

In each year of a multi-constraint analysis, one year's deterioration is applied to all deterioration-related variables across all road sections. Variables that change with each year are also modified as needed. In practical terms, this means that all Performance Index (PI) columns are now deteriorated for one year. (A Performance Index column is any column in the Network Master file that is defined as "deteriorating" [that is, has the Deteriorates check box selected in the PMS Columns in Analysis window]. These columns can be any numeric condition attribute that can be modeled by the application.)

Deterioration is accomplished for each column and road section by finding the appropriate one-year deterioration rate from the performance model based upon the section's currently assigned performance group or section model (if a section model exists). This deterioration is subtracted from the current PI value (at the beginning of the year) to get the estimated PI at the end of the year. In simulation, the performance index prediction for each year is determined by matching the performance curve to the pavement's current condition. Then the curve is extended by one year based upon the calculated age.

When treatments are applied during analysis, the deterioration rates are modified for each section by applying one of four post-treatment deterioration types as configured in the Setup Treatments window. Graphically, these types are represented as follows:

The following describes how the models are affected for each of the post-treatment deterioration types:

- Improvement with No Model Change: This model only changes the current condition of the pavement for the index. The next time the system calculates deterioration it will use the same model equation as used in the previous deterioration cycle. The system will apply a section model to the pavement if one exists; otherwise, it will use the appropriate Performance Class model.
- Improvement with Model Change: This deterioration type discards any current section model. Then, during the next deterioration cycle, the system chooses a new model from the available performance class models.
- Increase Index RSL by N Years: This deterioration type modifies the deterioration of the pavement by slowing its deterioration rate. The method used to apply this function ages the pavement only a reduced amount per year. The reduced age factor is determined by dividing the original RSL for the untreated section by the increased RSL.
- Improvement Deteriorates in N years: This deterioration model is normally applied for treatments that have a temporary effect on pavement condition. After application, the pavement's condition improves, but it then deteriorates at a faster rate over the effective life of the treatment. The amount of accelerated deterioration is determined by dividing the Improvement by the number of effective years. During the deterioration cycle the system deteriorates the pavement according to the original model for one year plus the additional, accelerated deterioration.

Improvement

At the end of each year of an analysis period, all road sections selected for rehabilitation have their condition(s) improved.

All road sections in this year's work plan come from two sources: either the MWP during initial analysis or through analysis in each year. In either case, a treatment is assigned to each section in this year. For each treatment, a performance index improvement is set for all defined performance indices and the performance indices are improved for all road sections that are in this year's work plan. (The improvement levels are defined by Treatment Improvement in the Calculated Expressions window. These expressions allow the user to define how the improvement is calculated from the attributes of the pavement section. In the Setup Treatments window, the user must specify the improvement expression used for each treatment and index column. If no expression is defined for a given Performance Index column, then the system applies no improvement. In addition, any other columns that are identified as changing due to the application of a treatment are also modified during this step.)

Once the system estimates improvements, the consequent changes in deterioration rates must also be assigned by changing the assigned model associated with each section.

Multi-year Analysis

The multi-year analysis method uses the same components as multi-constraint analysis with the following exceptions:

- It optimizes over the entire analysis period rather than a year at a time.
- In order to do that, the input into the integer programming engine is present value costs and multi-year benefit/condition formulations derived from multi-year alternative rehabilitation strategies. For every road section you supply as input several life cycle rehabilitation
strategies (using the Strategy Configuration and Section Strategies windows). The present value cost and multi-year benefit/condition calculations for each road section and strategy is then used as the input into the integer programming optimization engine. The result is selection of the best life cycle strategy per road section.

The shared components between multi-constraint and multi-year analyses are as follows:

- Use of decision trees (but, for multi-year analyses, in the strategy input phase rather than during analysis). Also, while INCBEN decision trees can be used in multi-year analyses, only the first recommended treatment of each decision tree limb will be used and the other two treatment options will be ignored.
- Use of deterioration (but, for multi-year analyses, in the strategy input phase rather than during analysis).
- Integer programming engine.
- The same options for objective function and constraints (but, in multi-year analyses, applied to the entire rehabilitation life cycle rather a specific rehabilitation recommended for a section in a given year).

Note: For typical multi-year analyses, every section must have a "no improvement" strategy because the engine must assign a strategy to every road section. If this strategy is missing, then in rehabilitating all sections costs are generated that violate constraints and so result in "no solution."

**Multi-year with Work Plan Analysis**

The Multi-year with Work Plan type of analysis is essentially the same as the Multi-year type of analysis. The difference is that the Multi-year with Work Plan only uses the treatments defined in the master work plan rather than pre-calculating the treatments as with the Multi-year type of analysis. The result of the Multi-year with Work Plan type of analysis is the projects and treatments that satisfy the constraints of the analysis.

**Prioritization**

Prioritization analysis is essentially the same as Ranking analysis, with the exception that a Groovy script is used to perform the ranking rather than values from the Calculated Expressions window. (The type of Groovy script is the Analysis Priority type.)

**Ranking Analysis**

The Ranking analysis type has all of the components of multi-constraint analysis except that a simple ranking criteria for improvement is used instead of the integer programming engine. Also, as with multi-year analysis, INCBEN decision trees can be used, but only the first recommended treatment of each decision tree limb will be used and the other two treatment options will be ignored.

The ranking criteria is user-defined using two expressions from the Calculated Expressions window as shown below:

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\text{Ranking Criteria} = \text{Analysis Priority} \times \text{Analysis Index Weight Factor}
\]

**Worst-first Ranking Analysis**

The Worst-first Ranking analysis type has all of the components of ranking analysis along with a predefined ranking formula. The formula uses the index selected in the Benefit Column field to rank all projects from the index value corresponding to "worst" to the index value corresponding to "best." It then includes as many of the ranked projects as the budget constraint allows.