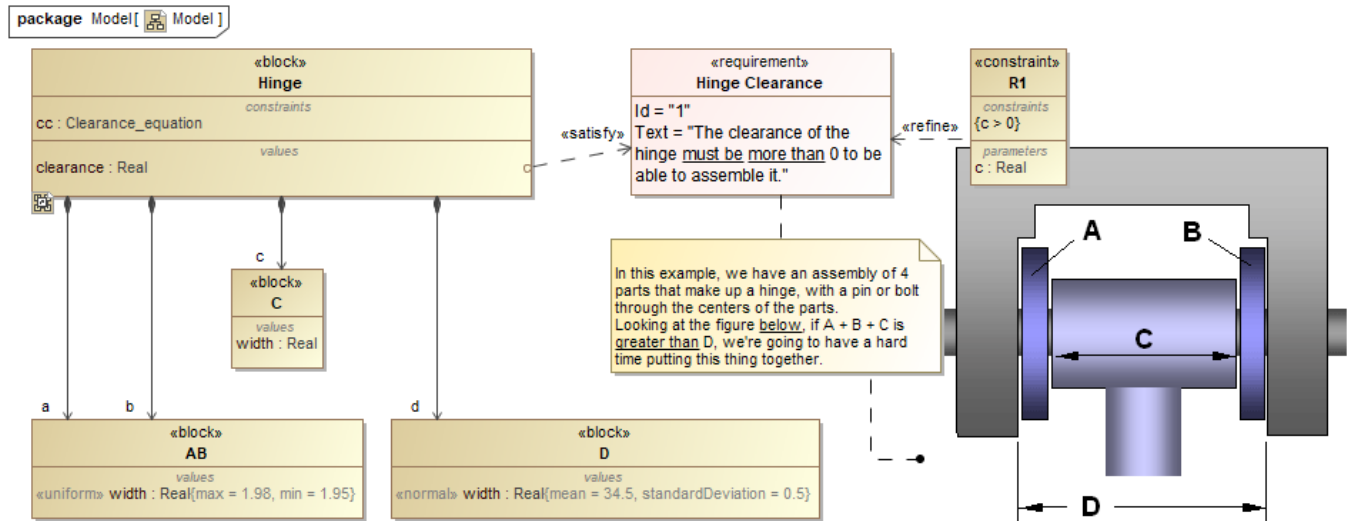


# Monte Carlo simulation

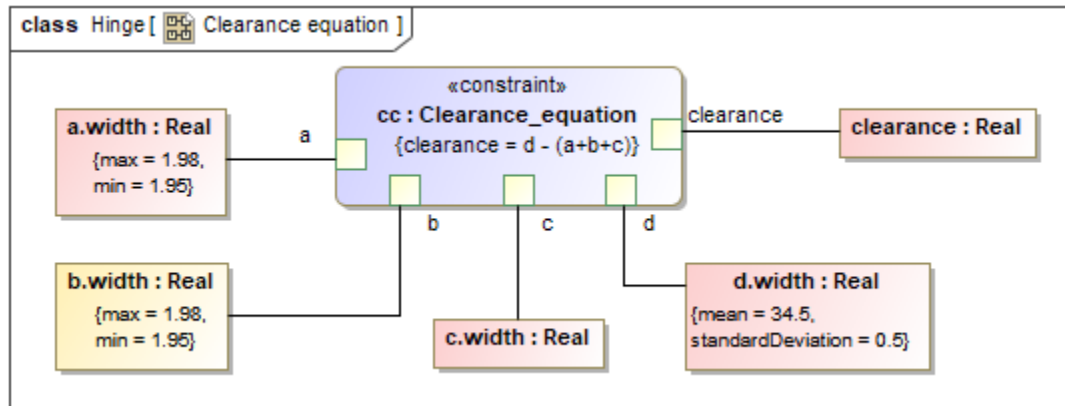
Cameo Simulation Toolkit introduces a built-in support for Monte Carlo analysis, allowing you to manage uncertainties and estimate how random variation of sensitive parameters affects the overall performance of the system being modeled. The [HingeMonteCarloAnalysis](#) sample model demonstrates the following steps.

1. Create a Block structure along with other parts in the Block Definition diagram. Apply [distributions stereotypes](#) to get a set of random inputs on value properties of the parts (e.g., the *Hinge* Block with *AB*, *C*, and *D* Blocks as parts with «uniform» and «normal» stereotypes on *width* value properties accordingly).



The Block Definition diagram of the Hinge model with distributed value properties applied.

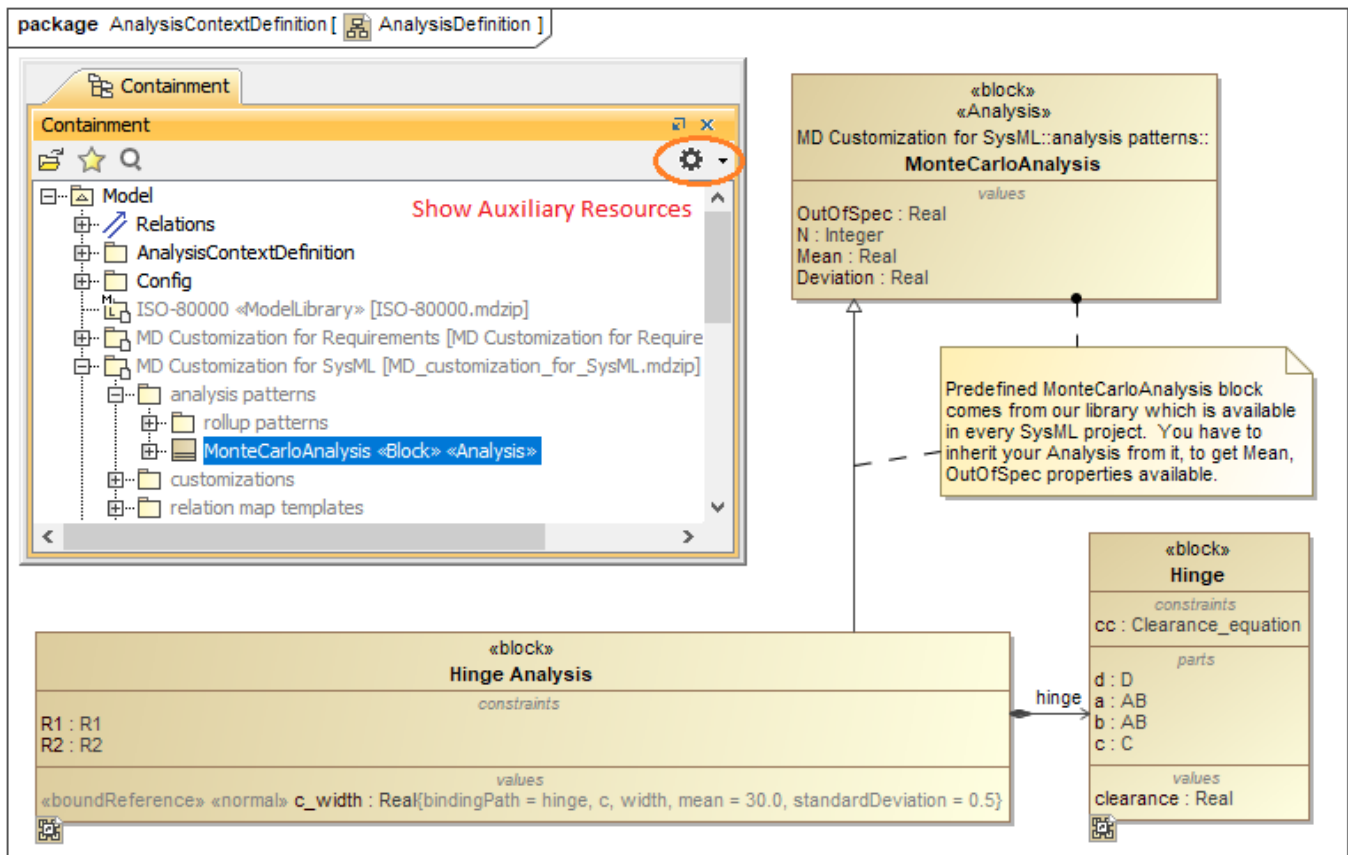
2. Create a Constraint Block of those value properties in the Parametric diagram according to the requirement (e.g.,  $clearance = d - (a + b + c)$ ).



The Parametric diagram of the Hinge model.

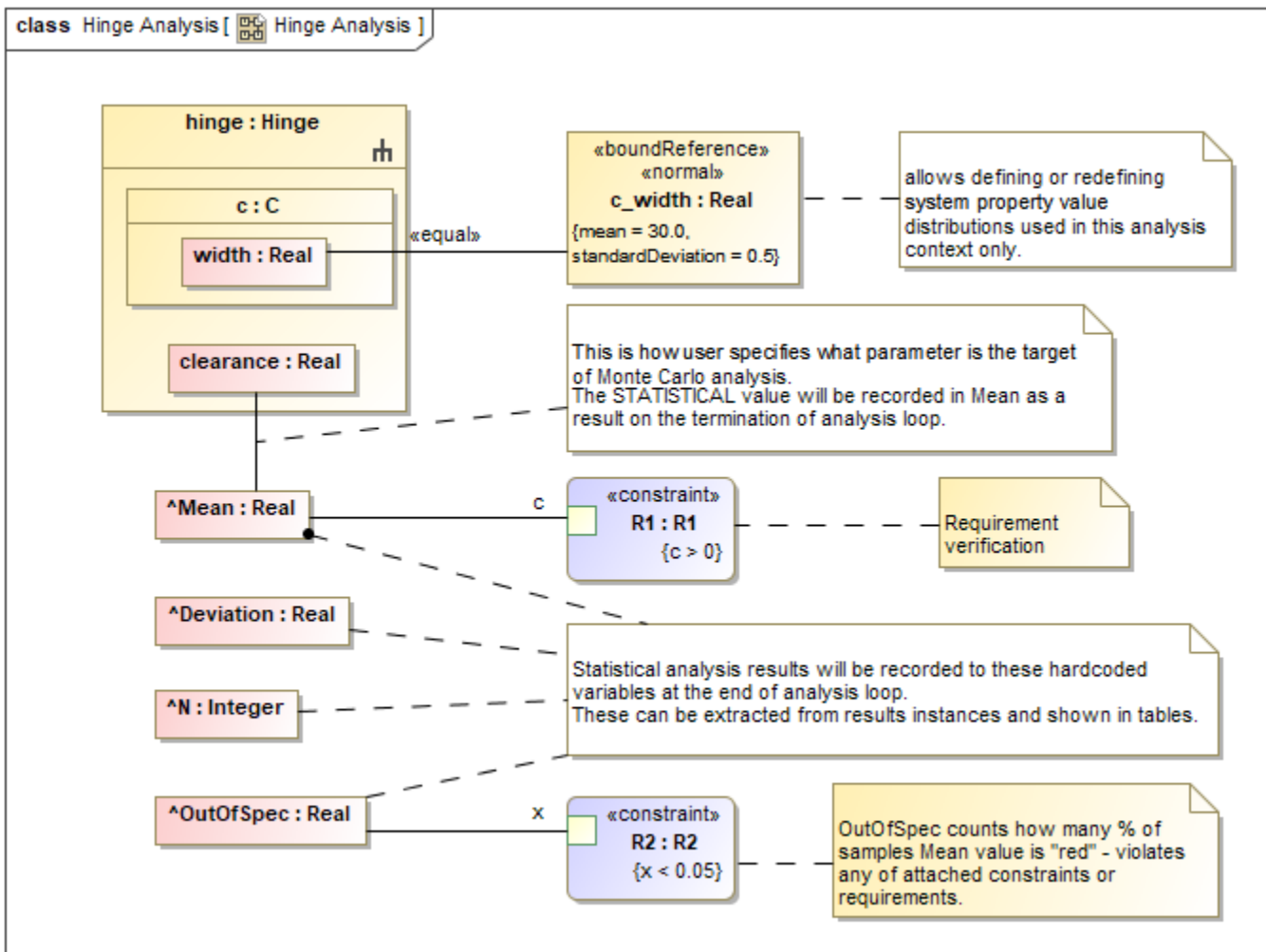
3. Create another Block Definition diagram to include an analysis context definition. In the Containment tree pane, click and select **Show Auxiliary Resources**. Drag the predefined *MonteCarloAnalysis* Block from the **MD Customization for SysML** library (available in every SysML project) into the Block Definition diagram.

4. Inherit your analysis context definition (e.g., the *Hinge Analysis* Block from *MonteCarloAnalysis* Block) to get *N*, *Mean*, *Deviation*, and *OutOfSpec* properties. Finally, you must set the *Hinge* Block as part of the *Hinge Analysis* Block.



Inheriting the Hinge Analysis Block from the predefined MonteCarloAnalysis Block and setting the Hinge Block as part of the Hinge Analysis Block.

5. Specify a parameter target, e.g., the *clearance* value property, of the Monte Carlo analysis in another Parametric diagram. Statistical values will be recorded in the Mean as a result of termination of the analysis loop. You must create Constraint Blocks and connect them to the *requirement verification* (R1) and the *OutOfSpec* property (R2) respectively.



Specifying the requirement verification (R1) and OutOfSpec property (R2) of the Monte Carlo analysis in another Parametric diagram.

6. Create a Simulation Configuration diagram, add a «[SimulationConfig](#)» to the diagram, and set the following tags:

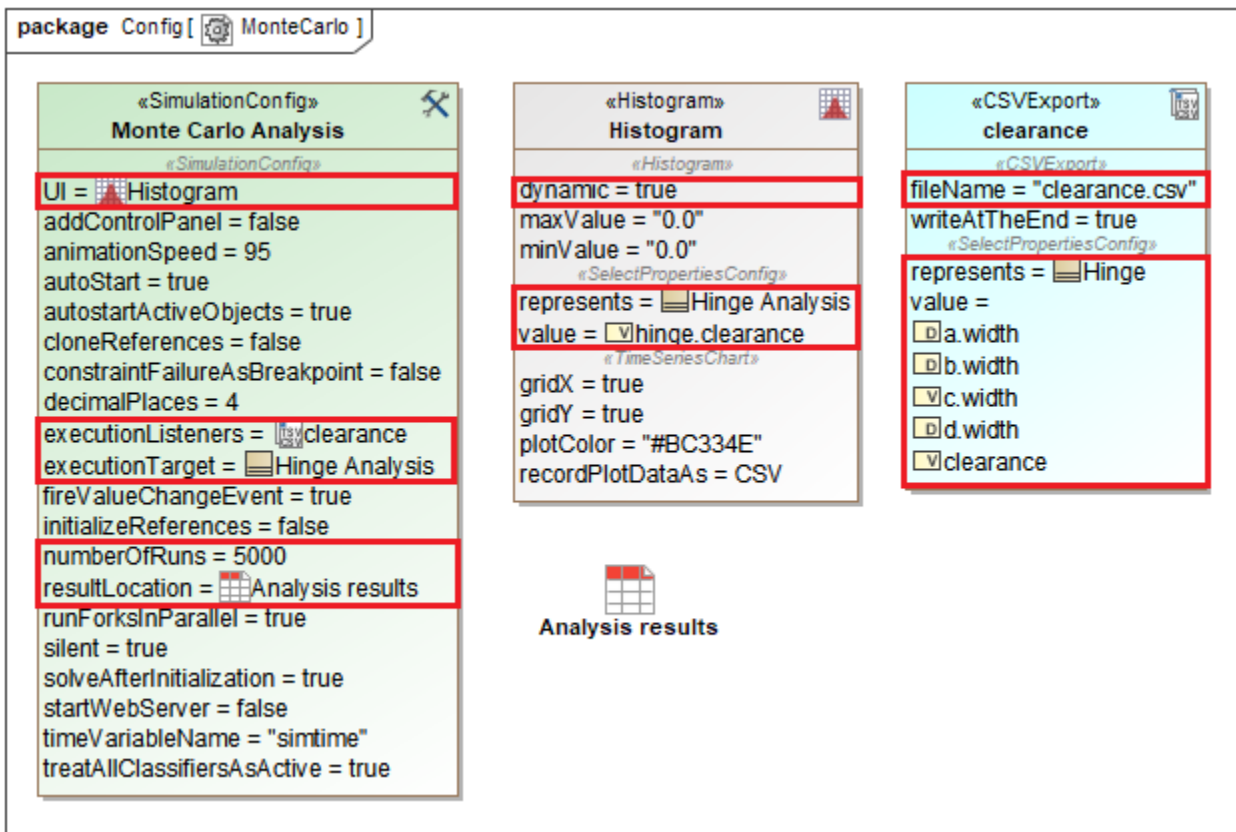
- *executionTarget*: Hinge Analysis Block.
- *numberOfRuns*: the number of runs, e.g., 5000.
- *resultLocation*: an Instance table, e.g., *Analysis results*.
- *silent*: true (for the optimum performance of the Monte Carlo simulation).

#### Note

- For a model that has Behaviors (Classifier Behavior and/or Part Property with Behaviors), see the *autoStart* tag in [SimulationConfig](#).
- If *numberOfRuns* of any table (*executionTarget*) is more than 1, it will be ignored in the Monte Carlo simulation. The table, however, will be run only once.
- If *silent* is set to false, the simulation will run with animation and idle time for each iteration, which is not practical for the Monte Carlo simulation.

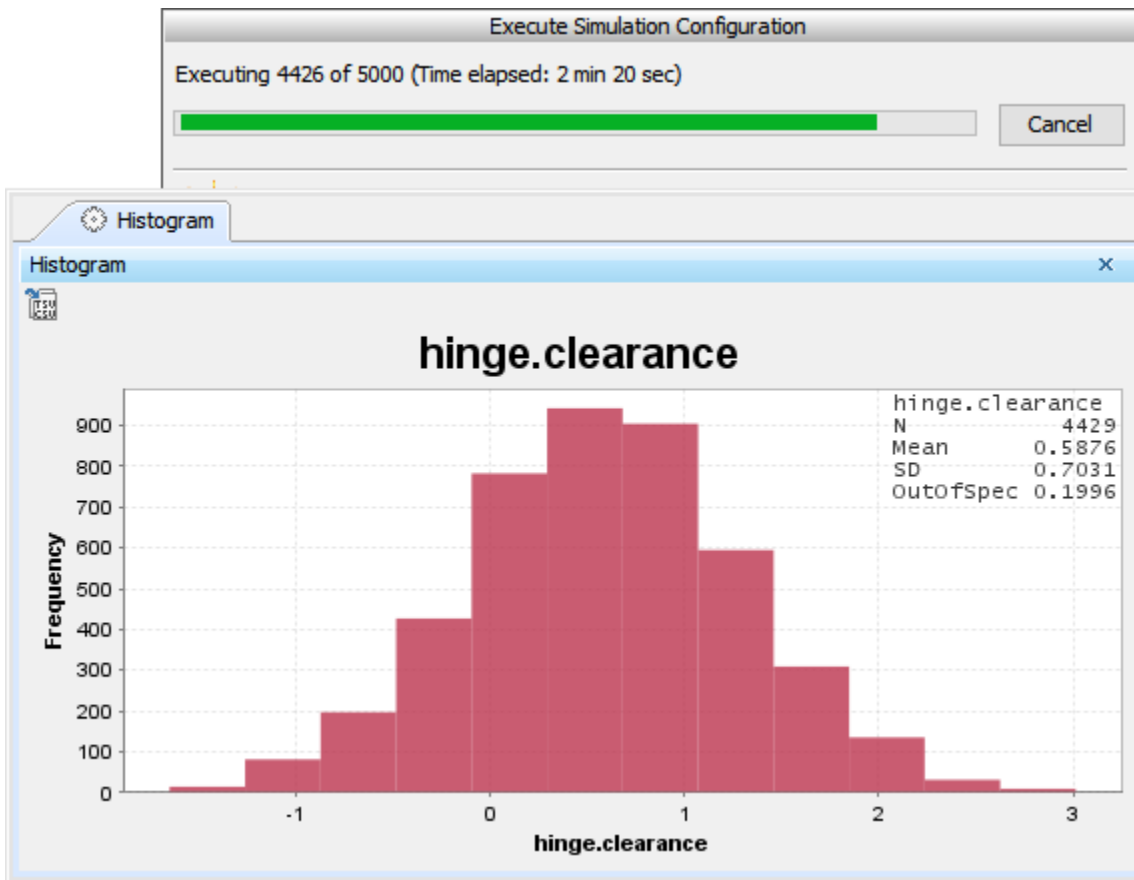
7. Drag a [Histogram](#) control from the **Simulation** toolbar to the Simulation Configuration diagram. You can use the histogram as a local user interface. Set the *represents* and *value* tags to the *Hinge Analysis* Block and to the *clearance* value property respectively. Set the *dynamic* tag to **true** to view the histogram that dynamically updates those statistical values (setting to **false** will open the histogram at the end of executions). You can also record the values of every iteration using the [CSV Export](#) control by setting the *represents* and *value* tags to the *Hinge* Block and other related value properties, e.g., *a*, *width*, to be in the exported CSV file.

8. Drag the [Histogram](#) and [CSV Export](#) controls to the «[SimulationConfig](#)». *UI* and *executionListeners* tags will be updated with the names of the *Histogram* control as *Histogram* and *CSVExport* controls as *clearance*.



«SimulationConfig» setting with numberOfRuns, Histogram, CSV Export, and Instance Table.

9. Run «SimulationConfig». The histogram will dynamically show the estimated distribution of the values of the analysis context definition of *hinge.clearance* during the simulation at the top right of the histogram. The simulation progress bar is shown and allows the user to cancel the simulation.



The histogram dynamically shows statistical results during the simulation.

10. Analysis results will be recorded in the **Instance** table along with [verification status](#). You can also see the detail of the constraint failure in the tooltip when hovering the mouse over any highlighted red values. The value properties with distributions stereotypes applied are exported to the **clearance.CSV** file.

| Analysis results                                                                            |                                    |                                      |      |         |      |                    |                    |
|---------------------------------------------------------------------------------------------|------------------------------------|--------------------------------------|------|---------|------|--------------------|--------------------|
| Criteria                                                                                    |                                    |                                      |      |         |      |                    |                    |
| Classifier: Hinge Analysis                                                                  |                                    | Scope (optional): MonteCarlo Results |      | Filter: |      |                    |                    |
| #                                                                                           | Name                               | OutOfSpec                            | R1   | R2      | N    | Mean               | Deviation          |
| 1                                                                                           | hinge Analysis at 2017.11.20 10.12 | 0.2464                               | pass |         | 5000 | 0.4887838265051705 | 0.7018004356454048 |
| 2                                                                                           | hinge Analysis at 2017.11.20 10.35 | 0.245                                | pass |         | 5000 | 0.4928090039179751 | 0.7072150256336678 |
| 3                                                                                           | hinge Analysis at 2017.11.20 15.37 | 0.2126                               | pass |         | 5000 | 0.5653308801211102 | 0.6976108816064522 |
| 4                                                                                           | hinge Analysis at 2017.11.20 17.51 | 0.2056                               | pass | fail    | 5000 | 0.583696355425563  | 0.7069343378560239 |
| Requirement 2 - "There could be no more than 5% of unassemblable hinges." is not satisfied. |                                    |                                      |      |         |      |                    |                    |

Analysis results are recorded in the Instance table with verification status.

|    | A        | B       | C       | D       | E       | F         |
|----|----------|---------|---------|---------|---------|-----------|
| 1  | time(ms) | a.width | b.width | c.width | d.width | clearance |
| 2  | 0        | 1.9699  | 1.9527  | 29.7489 | 34.1094 | 0.438     |
| 3  | 0        | 1.9719  | 1.9589  | 30.1333 | 34.3102 | 0.2462    |
| 4  | 0        | 1.9793  | 1.9689  | 29.5465 | 34.9699 | 1.4751    |
| 5  | 0        | 1.9607  | 1.9623  | 31.0178 | 35.0214 | 0.0807    |
| 6  | 0        | 1.9783  | 1.9779  | 30.2774 | 35.2926 | 1.0591    |
| 7  | 0        | 1.953   | 1.9504  | 28.786  | 34.5033 | 1.8138    |
| 8  | 0        | 1.9794  | 1.9584  | 29.6696 | 34.3921 | 0.7848    |
| 9  | 0        | 1.966   | 1.9579  | 30.4552 | 34.4694 | 0.0903    |
| 10 | 0        | 1.9517  | 1.965   | 30.2331 | 34.6525 | 0.5027    |
| 11 | 0        | 1.9654  | 1.9678  | 30.4735 | 34.7705 | 0.3638    |
| 12 | 0        | 1.9719  | 1.9655  | 29.8754 | 34.7032 | 0.8903    |
| 13 | 0        | 1.9782  | 1.9779  | 29.3136 | 35.0491 | 1.7795    |
| 14 | 0        | 1.971   | 1.965   | 29.5043 | 34.9351 | 1.4948    |
| 15 | 0        | 1.9561  | 1.9783  | 29.3873 | 34.0719 | 0.7502    |
| 16 | 0        | 1.9538  | 1.9629  | 29.9016 | 34.4221 | 0.6039    |
| 17 | 0        | 1.9795  | 1.956   | 30.1975 | 34.5067 | 0.3736    |
| 18 | 0        | 1.9608  | 1.9632  | 29.7818 | 34.5114 | 0.8055    |
| 19 | 0        | 1.961   | 1.9762  | 29.4141 | 34.683  | 1.3316    |
| 20 | 0        | 1.9797  | 1.9608  | 30.5296 | 35.7698 | 1.2997    |

Analysis results are exported to the clearance.CSV file.