Enhancing the Reporting and Analysis of Anomalies Using Systematic Fuzzy Data Methods and Software

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Main Points of Presentation

- Fuzzy data are systematically characterized for evaluation
  - Qualitative characterizations, categorical characterizations, quantitative intervals
- Using methods for handling fuzzy data , important information is obtained
  - Statistics, patterns, risk estimates
- Fuzziness and uncertainties are incorporated in the evaluations
- Software provides efficient implementation for large datasets
- Satellite anomaly data provide a rich source of fuzzy data that can be mined
- Example applications illustrate the information obtainable
- The applications are examples of techniques widely used in data mining

Example Fuzzy Characterizations of Satellite Anomaly Data

- Having MMOD qualitative likelihoods:

  “Improbable”, “Possible”, or “Probable”

- Having MMOD indicators:

  “Associated with Abrupt Changes”, “Associated with Trends”, “Associated with Multiple Effects”

- Having severity categories:

  “Very Low”, “Low”, “Medium”, “High”, or “Very High”

- Having fuzzy causes:

  “Possible Random Failure”, “Possible MMOD Impact”

- Having approximate penetrations:

  “Less than ~1 mm”, “~1 mm to ~1 cm”, and “Greater than ~1 cm”

Methods of Fuzzy Data Analysis

- Associate a range of possible values with each fuzzy category.
- Assign a membership function to the range:
- A simple but effective characterization is to treat all values in a range as being equally possible
- Combine the membership functions using interval operators and fuzzy operators
- For statistical analysis, the memberships are translated to likelihoods of possible values in the range
- Use computer software to efficiently carry out the evaluations which involve simulations and repetitive evaluations

Example Application of the Characterization and Analysis of Fuzzy Anomaly Data

- Two fuzzy anomalies are analyzed for their MMOD indications
- For the first fuzzy characterization, each anomaly is characterized as being “Improbable”, “Possible”, and “Probable” of being an MMOD hit
- For the second characterization, more detailed indicators are used to characterize each anomaly as being an MMOD hit
- The accumulated fuzzy MMOD count is determined and compared to model prediction
- Fuzziness and uncertainties are taken into account in the assessment
- Significant conclusions are obtained

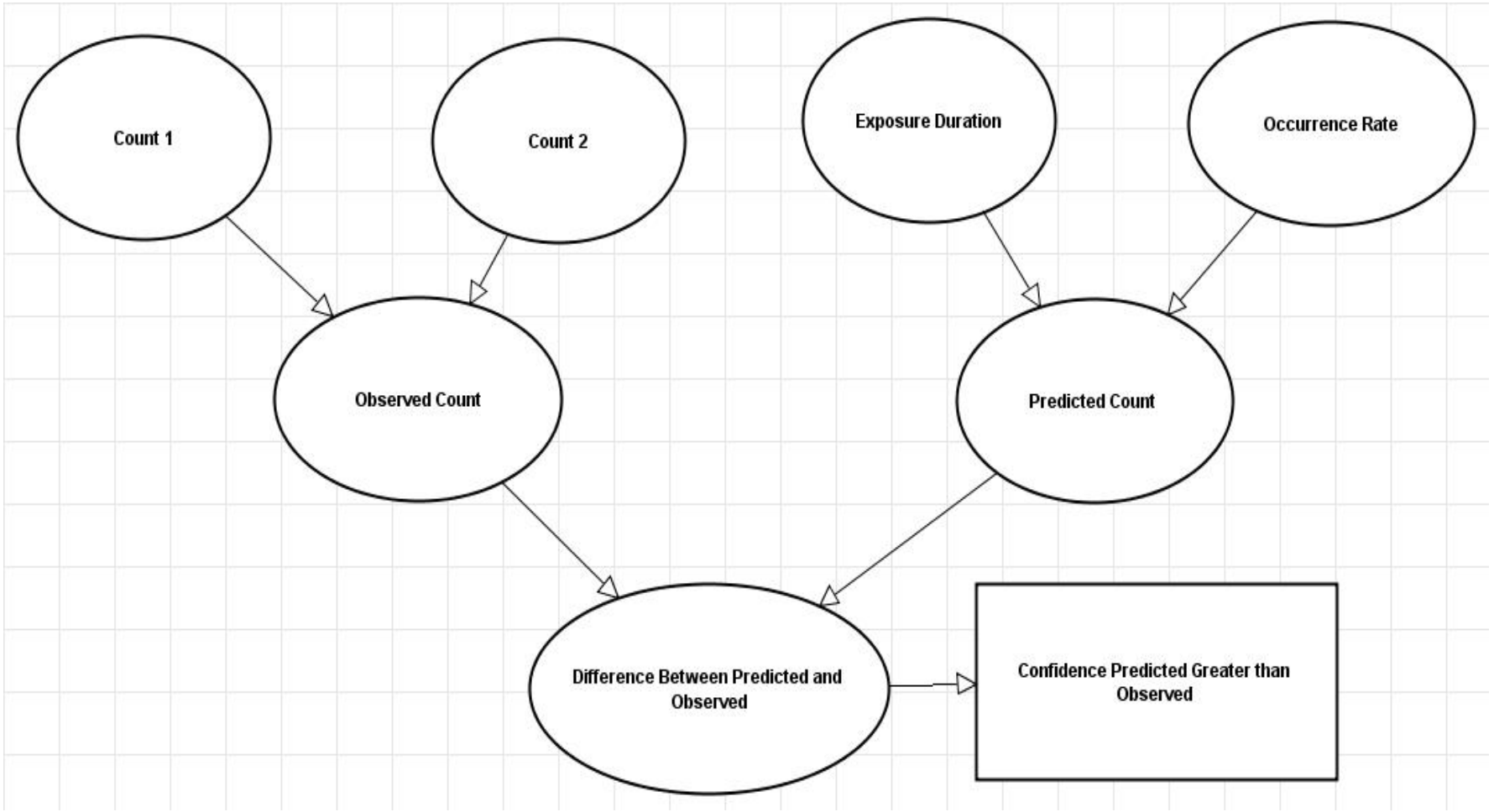
The Software Program AgenaRisk© is Used

- AgenaRisk© is used for the examples and is one of several available software packages that can handle probabilistic and statistical analysis of fuzzy data.
- AgenaRisk© is representative of network analysis programs that are widely used
- A free version of the software is available on the AgenaRisk© website
- Networks are graphically constructed to show the input data and relationships
- Fuzzy set analysis and fuzzy statistical analysis can be performed
- Fuzzy Bayesian analysis can also be performed to update prediction parameters with data but will not be used in the evaluations
- EXCEL© interfaces and detailed plots and tables are provided
- The results illustrate the types of information obtainable from such programs

MMOD Fuzzy Characterization for Each Anomaly:
Improbable
Possible
Probable

MMOD Count Accumulation Accounting for Fuzziness in Individual Counts

Comparison of Observed Versus Predicted Counts

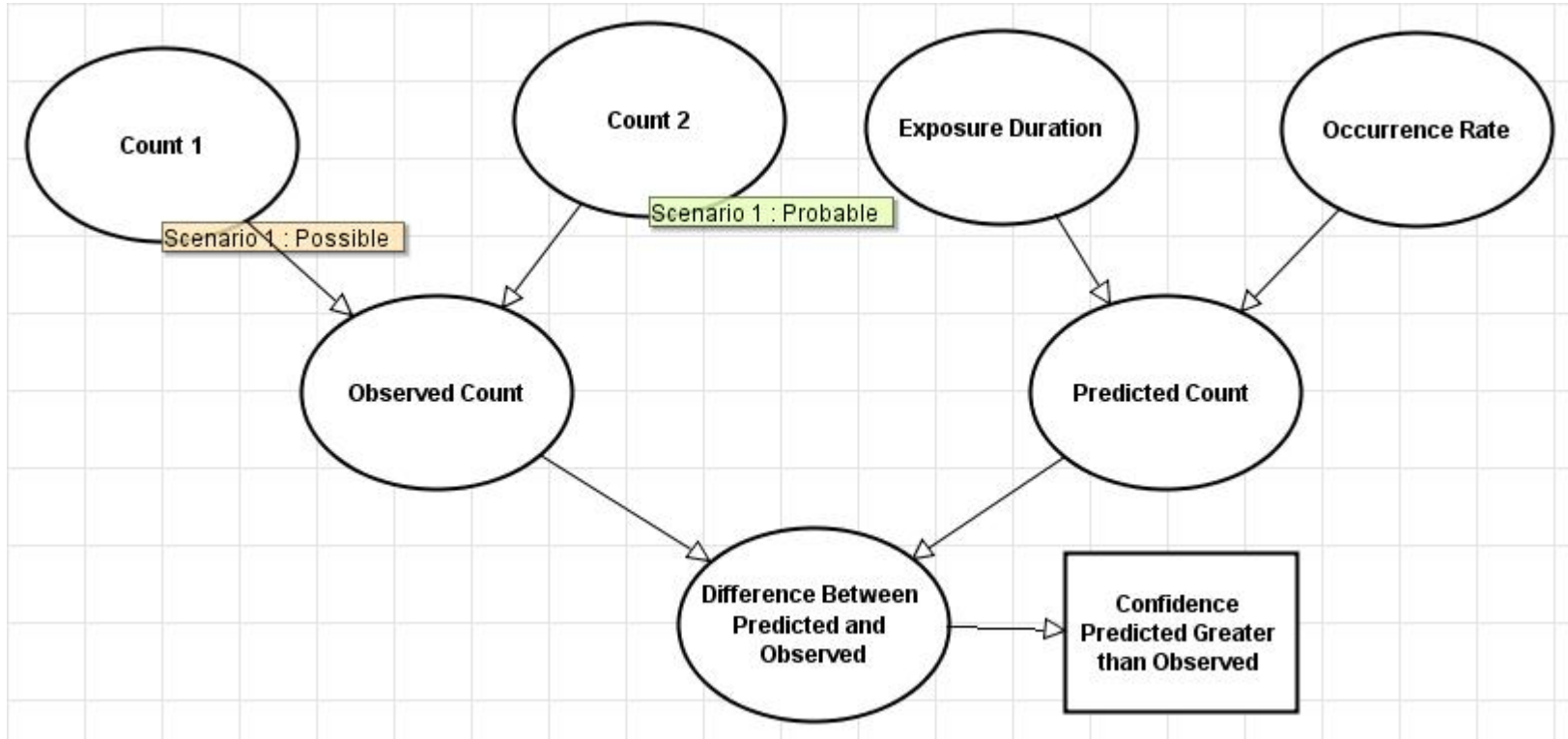


MMOD Prediction Parameters

Predicted MMOD Counts

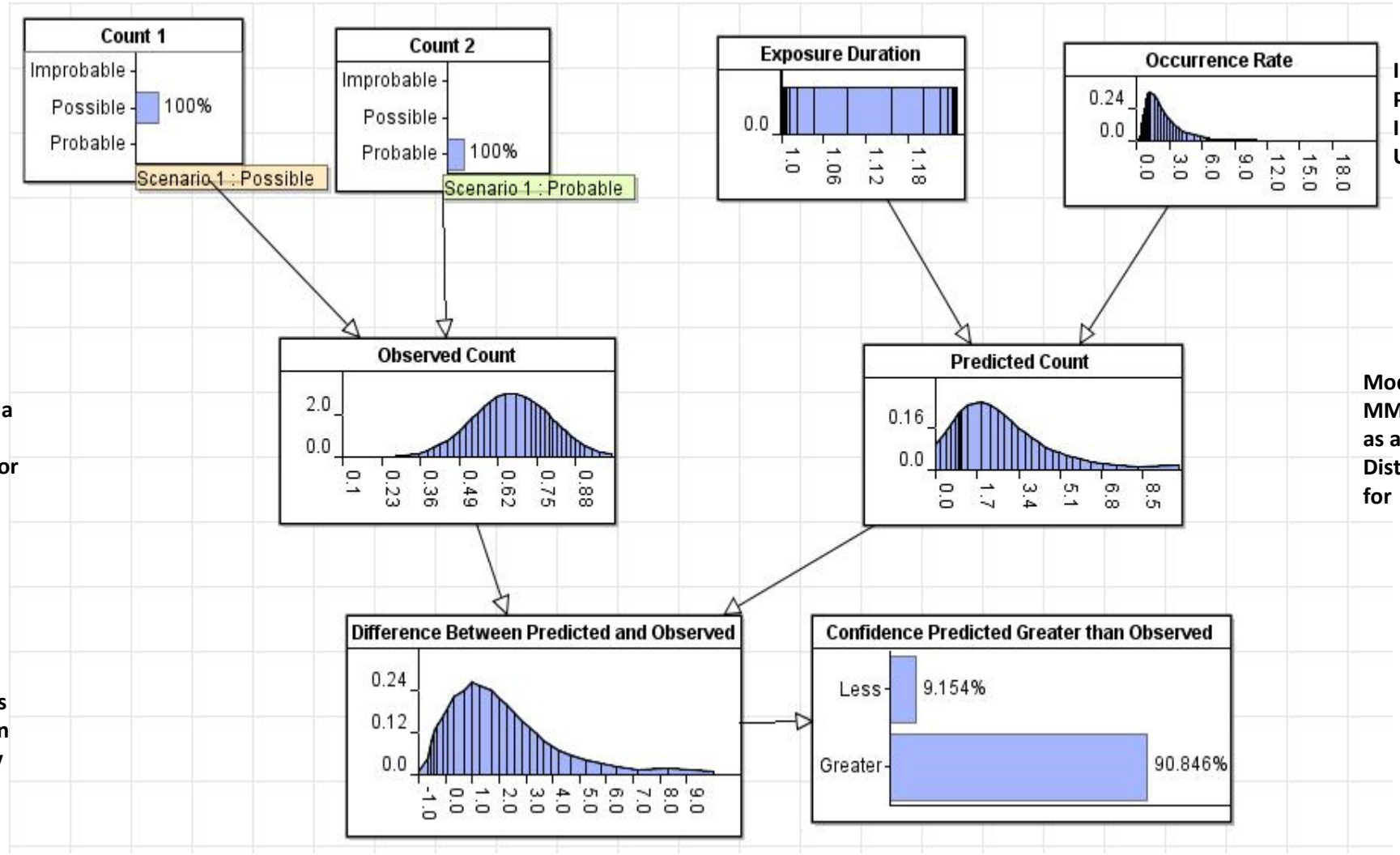
Confidence Predicted Count Greater Than Observed Count

Basic Network for Aggregating Fuzzy MMOD Observations and Comparing with MMOD Prediction



Network With Fuzzy MMOD Characterizations of the Anomalies Shown as Inputs (Scenario 1)

Input Observed Fuzzy MMOD Characterizations



Input Model Parameters Including Parameter Uncertainties

Accumulated Observed MMOD Counts Shown as a Fuzzy Count Probability Distribution Accounting for the Fuzzy Data

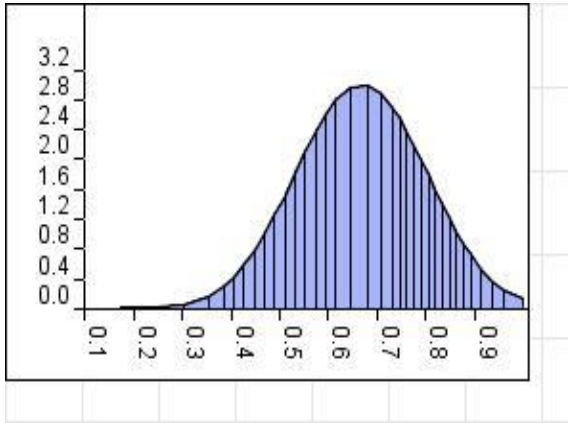
Model Predicted MMOD Counts Shown as a Count Probability Distribution Accounting for Model Uncertainties

Difference Between the Observed and Predicted MMOD Counts Shown as a Probability Distribution Accounting for the Fuzzy Data and Model Uncertainties

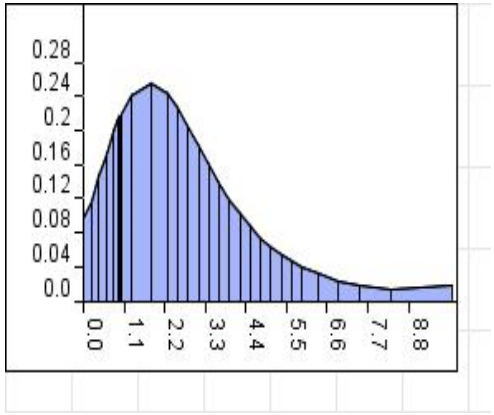
Confidence that Predicted Counts is Greater Than the Observed Counts Accounting for the Fuzzy Data and Model Uncertainties

Analysis Results of the Fuzzy MMOD Observed Count and Model Comparison

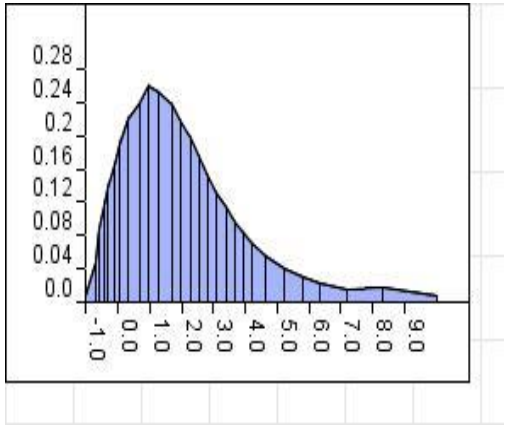
Detailed Graphical Outputs Display the Results



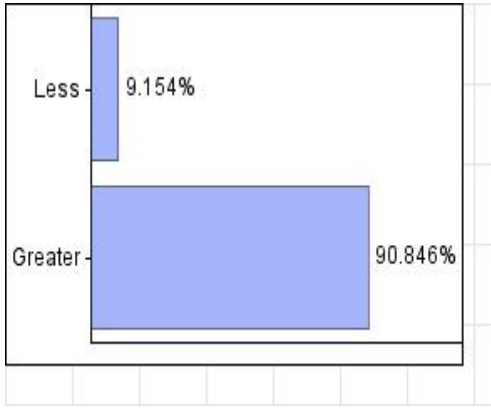
Observed MMOD Total Counts Accounting for the Fuzzy Data



Model Predicted MMOD Counts Accounting for Model Uncertainties



Difference of Predicted Minus Observed Counts



Confidence Predicted Counts Greater Than Observed Counts

Detailed Tabular Numerical Output

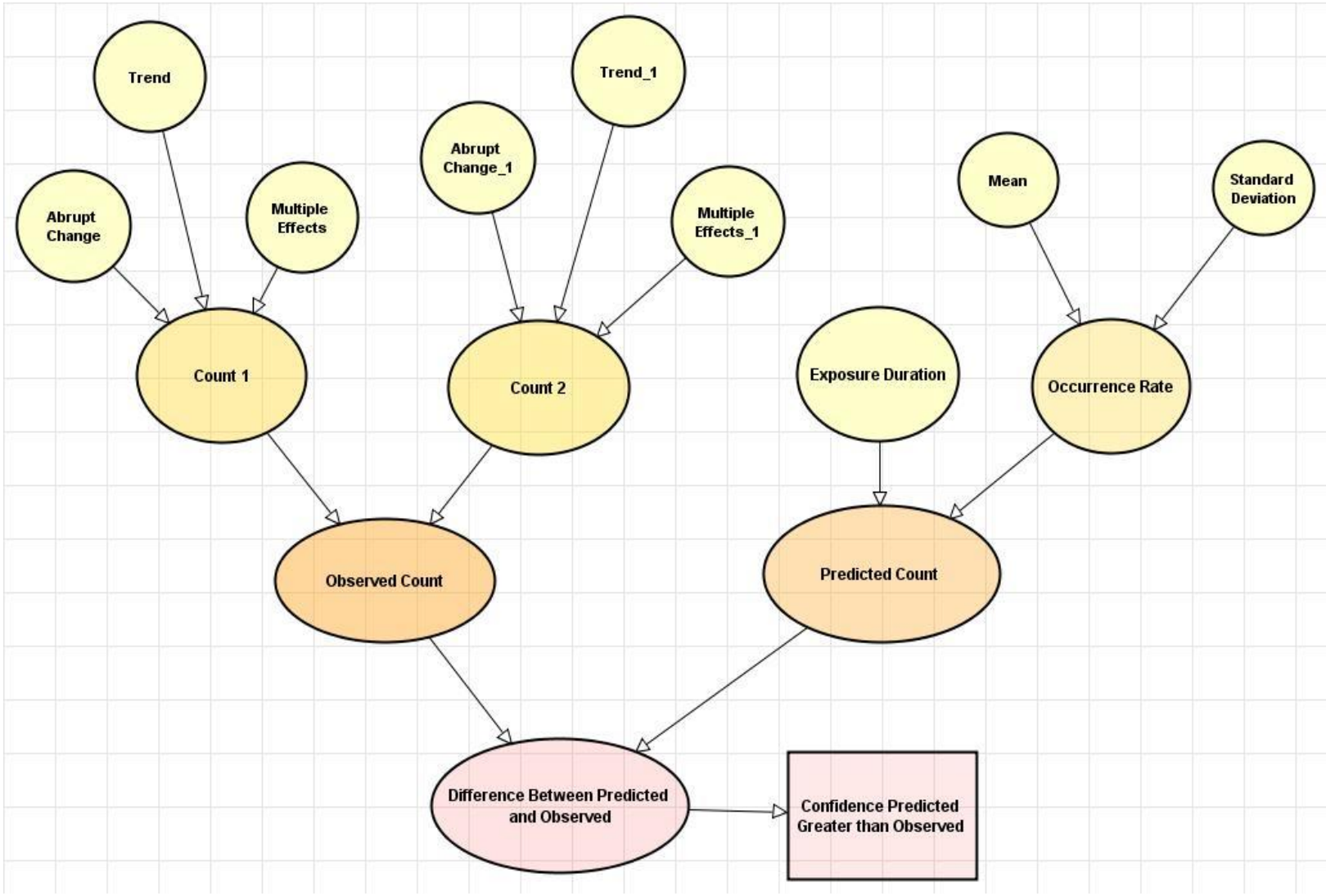
Risk Object	New Risk Object			
Node Name	**Difference Between Predicted and Observed**			
Node Id	DPO			
Summary Statistics				
Mean	2.163394226			
Median	1.726572829			
Variance	4.071118763			
Standard Deviation	2.017701356			
Lower Percentile [25.0]	0.717304169			
Upper Percentile [75.0]	3.084286775			
Lower Bound	**Upper Bound**	**Interval Probability**	**Probability Less Than**	**Probability Greater Than**
-1	-0.75	0.0020	0.0020	0.9980
-0.75	-0.625	0.0059	0.0079	0.9921
-0.625	-0.5	0.0110	0.0189	0.9811
-0.5	-0.375	0.0146	0.0335	0.9665
-0.375	-0.25	0.0171	0.0507	0.9493
-0.25	0	0.0407	0.0914	0.9086
0	0.1	0.0188	0.1102	0.8898
0.1	0.5	0.0877	0.1978	0.8022
0.5	0.9	0.0961	0.2939	0.7061
0.9	1	0.0260	0.3198	0.6802
1	1.5625	0.1413	0.4612	0.5388
1.5625	1.84375	0.0666	0.5277	0.4723
1.84375	2.125	0.0611	0.5889	0.4111
2.125	2.40625	0.0550	0.6439	0.3561
2.40625	2.6875	0.0486	0.6925	0.3075
2.6875	2.96875	0.0424	0.7349	0.2651
2.96875	3.25	0.0367	0.7716	0.2284
3.25	3.53125	0.0315	0.8032	0.1968
3.53125	3.8125	0.0270	0.8302	0.1698
3.8125	4.09375	0.0230	0.8532	0.1468
4.09375	4.375	0.0197	0.8729	0.1271
4.375	4.9375	0.0312	0.9040	0.0960
4.9375	5.5	0.0228	0.9268	0.0732
5.5	6.0625	0.0171	0.9439	0.0561
6.0625	6.625	0.0129	0.9567	0.0433
6.625	7.75	0.0169	0.9736	0.0264
7.75	8.875	0.0180	0.9916	0.0084
8.875	10	0.0084	1.0000	0.0000

Individual Anomaly MMOD Indicators
Alternatives for each indicator:
No Indication
Possible
Indication

Amalgamation of Individual Indicators for the Overall MMOD Indication of a Count

MMOD Count Accumulation Accounting for Fuzziness in Individual Counts

Comparison of Observed Versus Predicted Counts

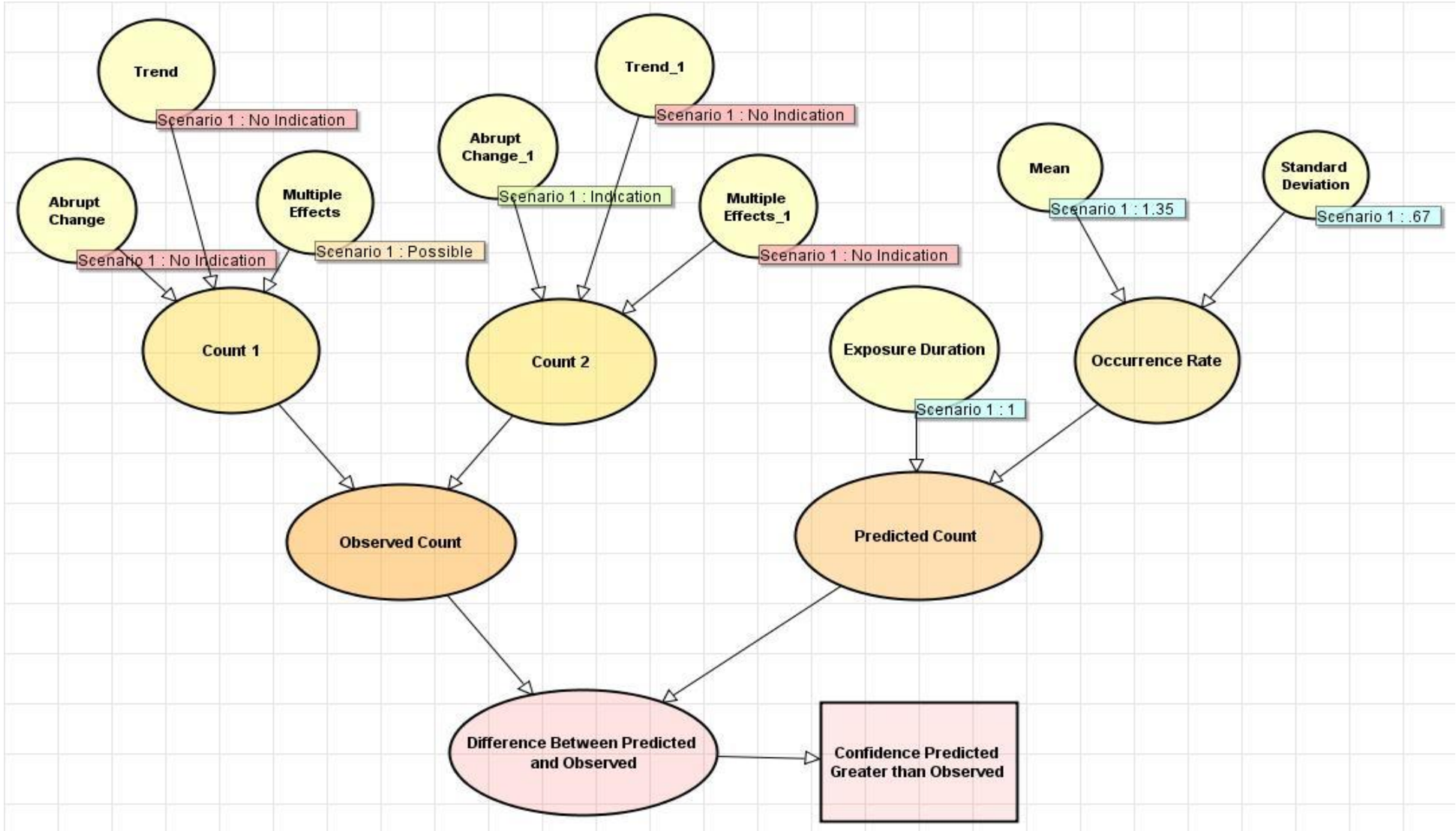


MMOD Predicted Occurrence Rate Parameters And Exposure Duration

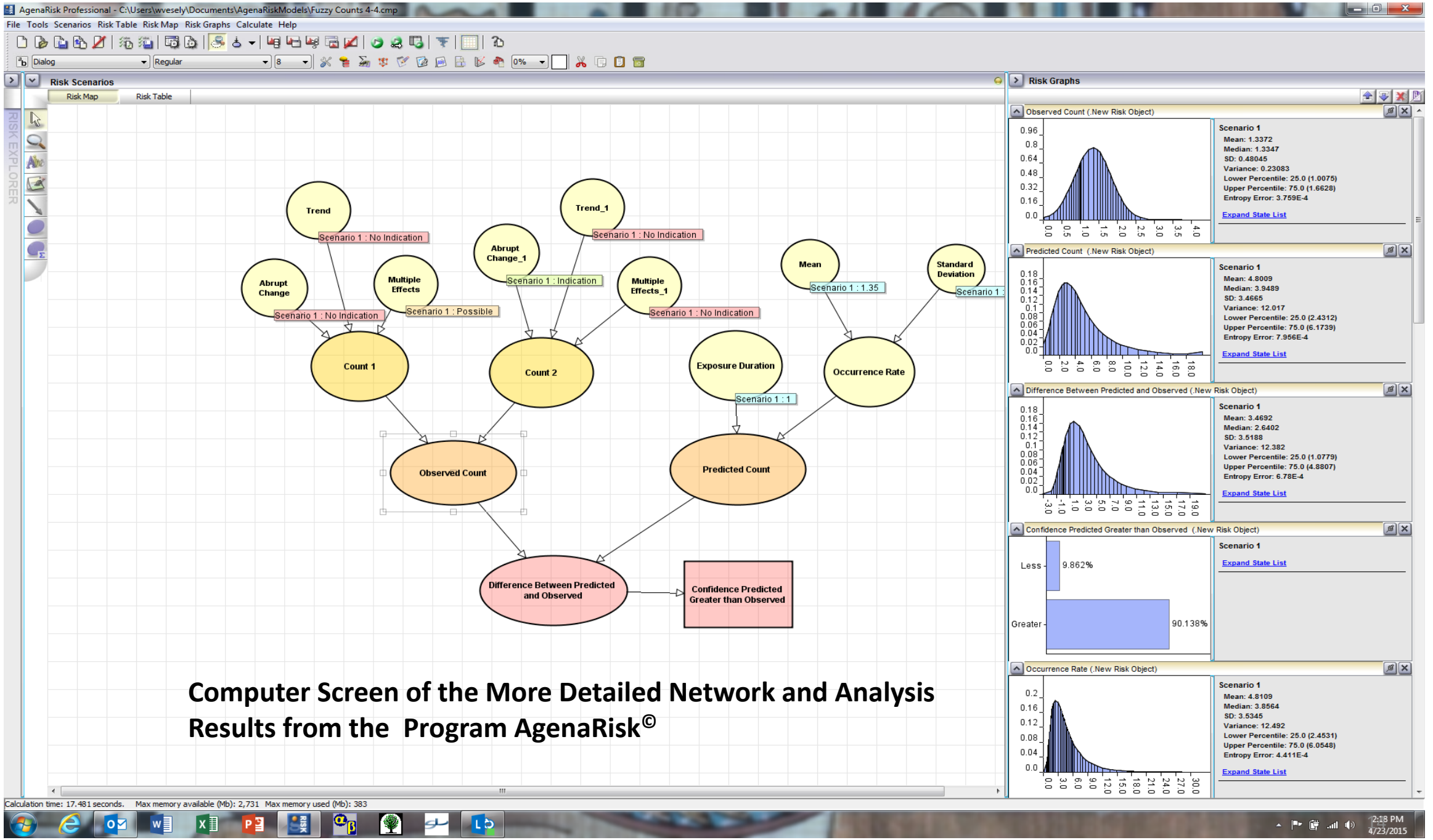
Predicted MMOD Counts

Confidence Predicted Count Greater Than Observed Count

Network with MMOD Indicators and Model Prediction Parameters



More Detailed Network with Anomaly MMOD Indicators and Model Prediction Parameters Shown as Inputs (Scenario 1)



Computer Screen of the More Detailed Network and Analysis Results from the Program AgenaRisk©

Summary

- Fuzzy anomaly data are systematically characterized to mine information
- The fuzzy characterizations can be fuzzy likelihoods
- The fuzzy characterizations can also be fuzzy indicators
- Using systematic fuzzy data methods, important information is thereby obtained
- Statistics, risks, and comparisons with prediction are examples of results
- Fuzziness and uncertainties are incorporated
- Software provide efficient implementation for larger datasets

References

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