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**Fiserv FraudNet**

**Digital Banking**

**January/2025**

**Model Documentation Change Log**

|  |  |  |  |
| --- | --- | --- | --- |
| **Author** | **Reviewer** | **Date** | **Details of the Changes** |
| EWB |  |  | Initial draft report created |
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# EXECUTIVE SUMMARY



## Objective and Background

Please provide a high-level description of:

* The model’s business objectives.
* Business background including history where appropriate.
* Related regulatory requirements that relate to the business objectives.
* Any other information you see appropriate.

Model Owner:

|  |  |
| --- | --- |
| **Model Name** | * *Please provide the official model-name that is used by the model owners and the MRM Group (mutually agreed).*   Model Owner: |
| **Primary Model Owner Entity** | * *Please provide the model owner business entity name, e.g., US, China, or Hong Kong.*   Model Owner: |
| **Primary Model Owner Group** | * *Please provide the model owner business group name.*   Model Owner: |
| **Model Owner** | * *Please provide the model owner names.*   Model Owner: |
| **Model Developer** | * *Please provide the model developer names (vendor name if vendor model).*   Model Owner: |
| **Model Production Process** | * *Please provide the model production process environment. A high-level description is encouraged.*   Model Owner: xxx |
| **Model User** | * *Please provide all model usernames along with business group names.*   Model Owner: xxx |
| **Portfolios the Model Applies to** | * *Please provide high level portfolio size and description that the model is applied to.*   Model Owner: xxx |
| **Model Objective** | * *Please list all model objectives at a high level.*   Model Owner: |

## Model Purpose & Use

### Model Purpose

For each business purpose, discuss the following in detail:

* The overall business purposes.
* The specific role that the model output plays in business use (for example, if the model output is used as a secondary source of information in the decision-making process, this should be detailed here).
* The specific products/portfolios/customers/transactions for which the model is suitable (e.g., types of retail mortgages, types of derivatives, types of consumer transactions, etc.)
* Any restrictions on model use, for example, excluded product types within product categories or transaction size limits.

Model Owner:

### Portfolio/Product/Transactions Overview

* Provide the current size of the portfolio of assets or liabilities (if applicable) and describe the history of the portfolio characteristics (e.g., the inception time frame, any notable idiosyncratic events such as mergers/acquisitions or asset sales, any notable management strategic changes, etc.)
* If the model is being applied to analyze transactions or events (e.g., debit card transactions analyzed for money laundering risk, or cyber-attacks on the Company’s infrastructure), provide the historical volumes of transactions and trends.
* Describe any specific product/customer/transaction types that are being proxied by other product types (e.g., a new product for which the model developed on a more seasoned product is applied).
* When applicable, please describe which portion of the portfolios/transactions/products that is supposed to be covered by the model (for the same business objective) but is decided to be excluded. For such portion, what business strategies are applied to ensure the same business objective is met (e.g., for BSA/AML purpose, certain transactions are monitored manually instead of using the BSA/AML model).

Model Owner:

### Applicable Policies and Regulations

* List and discuss all regulatory, accounting, legal, and/or compliance rules that are relevant to the model data, design, or use (if any).
* List and discuss all applicable internal policies relevant to the model design and use, if any.

*Note: Please provide document name including suffix.*

Model Owner:

### Existing Models

* If this model is replacing existing model(s), provide details of the existing model(s) and the rationale for the replacement.
* Discuss whether the existing model(s) will be retired once this model goes into production.

Model Owner:

### Upstream/Downstream Model Dependencies

* Provide a listing and description of upstream and/or downstream models or other key systems (e.g., the Empyrean ALM model).
* Discuss the impact of known limitations of upstream models on this model.

Model Owner:

### Process Flow Diagram

* Provide a process flow diagram showing how the model is used by the functional / business area. Include upstream and downstream models and systems listed in Section 1.2.5 Upstream/Downstream Model Dependencies.

Model Owner:

## Model Key Stakeholders, Change Management, & Outstanding Issues

Describe, at minimum, the following:

1. Model output key stakeholders, review committee(s).
2. High level summary of model changes in recent time or since last model validation.
3. High level summary of the latest model related business area audit and regulatory exam results including any outstanding findings, regulatory Matter Requiring Attention (MRAs), and management self-identified issues.

Please ensure that **all of** the points mentioned above are addressed.

# INPUT DATA INTEGRITY & APPROPRIATENESS

## MODEL DEVELOPMENT DATA

Model Development Data refers to the data used in the research & development process to determine the model specifications. That is, the process for determining the exact mathematical formulas, algorithms, inputs, parameters, and assumptions that comprise a model.

Note: This documentation section is not applicable for those models whose structure is not determined through empirical data analysis. This includes, for example, some market risk / trading models where the model structure is based on financial theory (e.g., Black-Scholes options pricing model) or qualitative models whose structure and parameters were determined judgmentally.

**Reference Document List**

Please list all the documents referred to in this section.

|  |  |  |
| --- | --- | --- |
| **#** | **Reference Document Name** | **High Level Description and purpose of the Document** |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |

**Data Assumptions Summary**

Please list out data assumptions applied in the model development and model production process, such as missing value treatment, outlier treatment, etc.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Assumption Name** | **Assumption Description** | **Materiality of Assumption** | **Rationales for this Assumption**  (Business driven or quantitative methodology driven) |
| 1 |  |  |  |  |
| 2 |  |  |  |  |

**Data Limitation Summary**

Please list out data limitations, their impact of business use, and ongoing monitoring program to appropriately manage the related risk.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Limitation Name** | **Limitation Description** | **Impact on Business Use** | **Monitoring Description & Frequency** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |

### Overview of Model Development Data

Provide descriptive characteristics of the model development data, for example, coverage of products / portfolios / transactions, time periods, geographic distribution, etc.

The sources and flows of all the data leveraged in model development should be illustrated with a data flow diagram. The diagram should show each stage of the data preparation process from the initial data pull to the final datasets used for model development and testing including data quality assurance controls.

Model Owner: xxxxxxx

### Development Data Sources, Extraction Process, and Reconciliation

#### Data Sources

Identify the sources of the model development data, for example, internal data from specific corporate data warehouse tables, desktop databases, text files, or external data from third-party vendors or websites. Development data may also include the output of other upstream models or computational tools.

If both internal and external data are used in the model development, you may want to create subsections covering them separately.

Model Owner: xxxxxxx

#### Data Relevance

Discuss the relevance of the development data to the modeling objective. For example, is the composition of the development data representative of the current portfolio in terms of coverage and distribution of data attributes? Is the time period selected for development data appropriate for the model’s business purpose and the statistical estimation technique?

If proxies for internal data are used, such as internal data for other products or external data from public databases or third-party services, justify and document the applicability and appropriateness of the proxy data to the specific internal portfolio / purpose.

For vendor models, document a comprehensive assessment of the vendor’s development data applicability to the Company’s internal portfolio/products/customers. This typically involves a comparison of the external and internal data for key model drivers (e.g., geographic distribution, loan/transaction size, loan/product type, etc.).

Model Owner: xxxxxxx

#### Data Extraction Process

Describe how the development data is extracted, either automatically or manually, or otherwise obtained.

Include references to the code or files used to extract the data or to the data files received from other individuals / departments.

Model Owner: xxxxxxx

#### Data Reconciliation

Demonstrate that the development data has been reconciled with a source system (e.g., the general ledger) or line of business report, or alternatively, explain how the extracted data was determined to be complete and accurate.

In addition, provide a step-by-step waterfall of data counts and balances at every step in the data preparation process from the raw data extract to the final modeling dataset.

Model Owner: xxxxxxx

### Development Data Preparation

#### Data Quality and Treatments

Describe the raw data quality and any treatments used to address missing or erroneous values, for example, algorithms applied to impute values.

Document any analysis of data outliers and their impact on model development / outputs. Provide support for the selected approach for treating the outliers (if any).

Model Owner: xxxxxxx

#### Data Filtering and Exclusions

Provide a detailed description of, and justification for, data filtering and significant data exclusions that may potentially introduce model bias. Where a significant number of records is excluded due to data quality or other reasons, to the extent possible, analysis should be performed and documented showing the impact of the filtering rule.

A complete waterfall from the point of raw data extract to the final development/testing data showing the impacts of each exclusion (in terms of the number of records and other key metrics) should be provided.

Model Owner: xxxxxxx

#### Data Sampling

Provide details of statistical sampling, if any, performed to create the model development and testing datasets.

Model Owner: xxxxxxx

#### Data Transformations

Provide a description of, and rationale for, operations/calculations on raw data, such as scaling, forming data segments, averaging, or combining data from multiples sources (for example, to calculate charge-off rates) in order to produce model development-ready data.

Describe the composite/derived variables created out of raw data. For example, splines, Weight-of-Evidence transformations of variables, interaction terms, etc. Provide support for the technical soundness and appropriateness of the selected transformations in the context of the specific modeling approach you selected and the overall model purpose.

Specifically:

For models that utilize feature engineering, provide detailed documentation of the engineering process, including a description of the software/package used to perform the feature engineering and a discussion on the limitations of the selected engineering approach.

For models that utilize unstructured data, include detailed description of the data pre-processing of unstructured data. Provide analysis/test/comparison results with related data/scripts/outputs if any to justify the pre-processing performed.

For advanced machine learning models, also include detailed discussion on the sufficiency and appropriateness of data transformations and treatments applied with respect to the ML algorithm used (for example, standardization/normalization is required for KNN but not for Random Forests). Provide analysis/test/comparison results with related data/scripts/outputs if any to support the discussion.

Model Owner: xxxxxxx

#### Variable Definitions

Provide definitions of variables, including alternative transformations of variables tested. For vendor models, describe how the vendor’s definitions for inputs and outputs compare with the Bank’s internal definitions (e.g., delinquency, defaults, accounting losses, etc.).

Reference the location of the comprehensive data dictionary that lists each variable’s description, source, allowable values, and other relevant information.

Response Variable

Describe the response/performance/dependent variable that the model is designed to estimate/project.

Model Owner: xxxxxxx

Explanatory Variables

Describe the explanatory/independent variable candidates assessed in the model development process.

Model Owner: xxxxxxx

### Data Limitations

Provide information about known data limitations / weaknesses and an assessment of their impact on the final model’s output. For example, if the model was developed based on external data that differs notably from the Bank’s data, the differences and their potential impact must be documented. For each noted weakness / limitation, describe how the associated risk is currently being mitigated. Additionally, where longer-term remedial actions are being undertaken or planned (e.g., an initiative to clean up the existing data or collect incremental data), such actions should also be documented.

Model Owner: xxxxxxx

### Data Preparation Software / Platform

Provide information on the software and/or programming language used in the data extraction, transformation, and other steps to prepare the model development and testing data. Provide a reference to the location of the development programming codes, associated log files, and other data preparation artifacts.

Model Owner: xxxxxxx

### Data Retention

Describe where the development data is stored (post development) and how the environment is controlled. Provide the minimum time period for data retention.

Model Owner: xxxxxxx

# CONCEPTUAL SOUNDNESS

## MODEL THEORY AND ASSUMPTIONS

**Reference Document List**

Please list all the documents referred to in this section.

|  |  |  |
| --- | --- | --- |
| **#** | **Reference Document Name** | **High Level Description and purpose of the Document** |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |

**Model Assumption Summary**

Please list out model methodology assumptions applied in the model development and model production process, such as missing value treatment, outlier treatment, etc.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Assumption Name** | **Assumption Description** | **Materiality of Assumption** | **Rationales for this Assumption**  (Business driven or quantitative methodology driven) |
| 1 |  |  |  |  |
| 2 |  |  |  |  |

**Model Limitation Summary**

Please list out model methodology related limitations, their impact of business use, and ongoing monitoring program to appropriately manage the associated risk.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **#** | **Limitation Name** | **Limitation Description** | **Impact on Business Use** | **Monitoring Description & Frequency** |
| 1 |  |  |  |  |
| 2 |  |  |  |  |

### Model Theory and Methodology

#### Modeling Approach

Provide a description of the modeling approach you have selected, including the statistical estimation approach or machine learning technique, if applicable (with further details of the model construction/estimation process to be provided in Section 3.2 Model Estimation/Training and Selection).

For advanced Machine Learning (ML) models, discuss briefly whether a self-explanatory or less complex model (e.g., logistic regression, linear regression) is viable in solving the same business problem. If not, explain why not. Detailed information on this topic should be provided in Section 3.1.1.3. Alternative Approaches Explored

Model Owner: xxxxxxx

#### Model Structure/Formulae

*Detail all relevant mathematical equations applied in the model with a clear explanation of the notation*. Describe the model inputs and outputs if not already provided in Section 2.1.3.5. Variable Definitions

Note: This section applies to all models and should be especially detailed for models that were not developed through statistical or machine learning analysis of empirical data (e.g., the market risk / trading models based on financial theory). For these models, the rationale for the particular choice of inputs (e.g., prices, interest rates, volatilities, variance/covariance matrices) should be provided.

Model Owner: xxxxxxx

#### Alternative Approaches Explored

Describe how the selected model theory/methodology (and estimation technique, if applicable) compares with industry practices for similar models and provide rigorous support for a selected approach that is non-standard or innovative. Provide references to industry and academic publications supporting the choice of this modeling methodology.

Describe alternative modeling approaches (including alternative estimation/numerical techniques, if applicable) that were considered and why they were not selected. Provide references to industry and academic publications discussing the alternative methodologies.

For machine learning (ML) models, provide performance comparison between the self-explanatory model and the selected ML model and a discussion on the trade-offs between model performance and transparency/interpretability. If a self-explanatory model is viable, also provide analysis/test/comparison results with related data/scripts/outputs if any to support the discussion.

Provide a comparative narrative for the selected ML model vs. other comparable/state-of-the-art methodologies with a discussion on the advantages and disadvantages of the selected ML model vs. the alternatives.

Model Owner: xxxxxxx

### Segmentation Approach

Describe and justify the selected model segmentation scheme (or lack thereof), including any related quantitative analyses performed and subject matter expert qualitative considerations. Provide the segmentation waterfall logic, if applicable. Assess the impact of the selected segmentation scheme on the model estimation and output.

If in-model segmentation approach was followed (rather than developing separate equations/model objects for each segment), explain this with the rationale for going the route of in-model segmentation.

Model Owner: xxxxxxx

### Model Settings

If applicable, describe model settings and parameters, including vendor model customizations. For example, a vendor model may offer alternative interest rate term structures for valuation purposes. or a vendor may recommend updated model tuning parameters (e.g., for mortgage prepayment models) to be used in place of default values. For each setting/parameter, justify the selected value relative to the other choices available.

Model Owner: xxxxxxx

### Model Assumptions

List and justify the implicit and explicit assumptions associated with the model, including qualitative or quantitative expert judgments. Assess the impact of each assumption to the extent possible. For example, if a model relies on an average of historical values over the last 6 months, it may be important to test the impact on the model output of selecting alternative assumptions, e.g., 3 months, 9 months, etc.

If any assumptions are intended to be conservative, explain in what way they are conservative.

NOTE: Testing of any technical assumptions underlying the selected statistical/machine learning technique should be documented in Section 3.3.1. Statistical and Technical Assumptions Testing.

Model Owner: xxxxxxx

### Model Limitations and Weaknesses

List any known model limitations and weaknesses. For each weakness / limitation, there should be a description of the associated model risk and, if applicable, the risk mitigant designed to address this risk. See the following example:

| ***Model Weakness or Limitation*** | ***Associated Model Risk(s)*** | ***Model Risk Mitigants / Remediation*** |
| --- | --- | --- |
| The model output is heavily impacted by several judgmental management assumptions, including x, y, and z. These assumptions are currently lacking empirical support. | Use of judgmental assumptions increases the risk of poor model predictions / measurements and unsupported model estimates, which may lead to inappropriate business decisions. | **Short Term Risk Mitigants**:   1. The judgmental assumptions will be subject to oversight by the governance committee X that will review and challenge the model owner's support for the assumptions on a monthly basis. 2. The model output will be benchmarked to the output from the alternative model Y on a quarterly basis. Significant divergence in the outputs will be investigated.   **Longer Term Remediation Plan**:   1. The model owner will investigate the possibility of obtaining empirical support for the assumptions x and y once an additional 6 months of data are collected. 2. The model owner will investigate the possibility of modifying the modeling approach to reduce the reliance on judgmental assumptions. |

Model Owner: xxxxxxx

|  |  |  |
| --- | --- | --- |
| ***Model Weakness or Limitation*** | ***Associated Model Risk(s)*** | ***Model Risk Mitigants / Remediation*** |
|  |  |  |
|  |  |  |
|  |  |  |
|  |  |  |

## MODEL ESTIMATION / TRAINING AND SELECTION

Note: “Model estimation/training” is mostly applicable for those models that rely on statistical estimation and optimization techniques, such as regression analysis or machine learning techniques. However, this section is also relevant to some other types of models, including those that are developed using expert judgment (qualitative models).

**Reference Document List**

Please list all the documents referred to in this section.

|  |  |  |
| --- | --- | --- |
| **#** | **Reference Document Name** | **High Level Description and purpose of the Document** |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |

### Estimation Methodology and Assumptions

Describe in detail the model estimation methodology, including the assumptions that may be implicit in the estimation technique. For example, ordinary least squares estimations include assumptions about regression residuals. Describe any expert judgments related to the estimation, such as the selection of variable weighting methodologies.

For machine learning (ML) models, discuss whether monotonicity of relationships between the model features and the target variable is important or required, and whether the ML algorithm is configured to ensure such monotonicity.

Model Owner: xxxxxxx

### Modeling Software / Platform

Provide information on the software and/or programming language used in the model estimation/training (including the version number, if applicable). If relevant, list the specific algorithms and packages used in model training.

Model Owner: xxxxxxx

### Hyper-parameter Tuning

For machine learning models, include a detailed description of the hyper-parameter tuning process, including the following information:

* The approach used for hyper-parameter tuning, including the rationale for leveraging this approach.
* The list of the hyper-parameters tuned (as well as those that are left at default values) and the range of values searched. If applicable, explain why some hyper-parameters were not tuned.
* Performance metric(s) used to select the optimal hyper-parameters and the supporting rationale.
* Sufficiently detailed discussion of the results of the tuning process and selected values, including any judgmental adjustments to the parameters, if any.

If the model also utilizes pre-training during development, provide details of the pre-training process and the pre-trained model as well as related analysis/test/comparison results.

Model Owner: xxxxxxx

### Feature / Variable Selection

Describe in detail the approaches used to select candidate and final model variables/features, including the relevant criteria/thresholds for quantitative selection criteria, as well as any expert judgments.

Describe the process for involving subject matter specialists from the line of business to obtain their views on candidate variables, including the associated economic theory/business intuition behind each variable, as well as the expectation for the directional impact of each variable on the model output.

Describe any algorithms or statistical procedures (such as correlation analysis, Information Value analysis, stepwise regression procedure, etc.) used as part of the process to select final model variables from the full set of candidate model variables.

Model Owner: xxxxxxx

### Model Estimation / Training Results

**For statistical models,** provide statistical estimation results for the final model, as well as other model structures that were considered to be strong candidates. Estimation results should include not only the estimated coefficients, but also the t-statistics and associated p-values, measures of model fit, and summary of results of the appropriate statistical diagnostic tests (detailed statistical testing should be documented in the Statistical Testing section).

In addition to providing the estimation results, explain why this model was selected (relative to other candidate models), including both quantitative and qualitative factors.

**For machine learning models:**

* Provide a listing of the full set of features included in the final model.
* Provide a feature importance chart showing the top X most important features in the final model.
* Provide information on the number of features that contribute 90%, 95%, and 99% of model fit. If the number of features providing the last 1-2% of model fit is significant, explain the rationale for their inclusion.

**For both statistical and machine learning models**, this section should contain for each feature an explanation of the economic theory/business intuition for the inclusion of this feature, as well as the assessment of the estimated directionality of the relationship between the feature and the target variable relative to the a priori expectations. For simple statistical models this assessment can be accomplished through the evaluation of the estimated coefficient signs. For complex statistical and machine learning models, use of explainability testing techniques is required (refer to Section 3.3.5 Model Explainability Testing).

Model Owner: xxxxxxx

#### Judgmental Adjustments

Describe and justify any judgmental overlays/overrides of statistically estimated input parameters. If any such adjustments are intended to be conservative, explain in what way they are conservative. Note: this section should not be used to detail any overlays/overrides to the model outputs (described in Section 3.3.11. Need for Model Overlays).

Model Owner: xxxxxxx

### Other Types of Model Estimation

#### Model Calibration

If applicable, describe the calibration process for models that are regularly fit to market data.

Model Owner: xxxxxxx

#### Vendor Model Tuning

If applicable, describe the process and results for any customization of vendor models (e.g., tuning of vendor model behavioral model parameters to Bank portfolio credit or prepayment experience) that is analogous to a statistical estimation.

Model Owner: xxxxxxx

## Model Development Testing

For each test discussed in the following subsections, include the purpose of the test, the testing methodology, the criteria used to evaluate test results (that is, the applicable metrics and thresholds), and a summary of the results with commentary and conclusions. For any anomalous results, the conclusions should include information on the impact of these results on the model outputs and business use, and whether they require any specific risk mitigant.

The level of detail for the testing documentation should be sufficient to provide a clear and definitive basis for the model owner’s conclusions about model’s performance and robustness.

**Reference Document List**

Please list all the documents referred to in this section.

|  |  |  |
| --- | --- | --- |
| **#** | **Reference Document Name** | **High Level Description and purpose of the Document** |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |

### Statistical and Technical Assumptions Testing

For statistical and any other models that include statistical and other technical assumptions, provide testing of all assumptions associated with the selected estimation technique (e.g., for Ordinary Least Squares models on time series data this includes testing for multicollinearity, heteroscedasticity, non-normality of errors, autocorrelation, non-stationarity, seasonality, etc.).

For vendor models, to the extent that the assumptions testing information is available from the vendor, include the model owner’s assessment of the testing results and any associated risks.

Model Owner: xxxxxxx

### Model Performance / Fit Testing

Provide testing of model performance / fit on the estimation and hold-out samples, including calculations of relative and absolute model errors for different population/product/portfolio risk segments and time periods. For some models, their fit can be evaluated using various additional statistical metrics and analytical techniques. This includes, for example: the K-S test, ROC curves (and AUC/Gini coefficient and similar measures of discriminatory power), lift charts, Precision/Recall, F1 score, risk profiling, etc.

For vendor models, include the model owner’s assessment of the model performance/fit testing results provided by vendor (based on vendor’s data) and any associated risks. In addition, include testing results on the Company’s internal data (or explain why it is not feasible).

#### **In-sample Performance/Fit**

Use this section for the testing of model performance/fit on the data on which the model was estimated/trained.

Model Owner: xxxxxxx

#### **Out-of-sample (but not out-of-time)**

Use this section for the testing of model performance/fit on data from the same time period as the in-sample estimation/training data but held out for model testing purposes.

Model Owner: xxxxxxx

#### **Out-of-time**

Use this section for the testing of model performance/fit on data from the time period different from the in-sample data, and not used in the estimation either because it was not yet available at the time of model estimation, or because it was available but excluded from the estimation/training for the express purpose of performing out-of-time model fit testing.

Model Owner: xxxxxxx

### Model Stability and Overfitting Testing

Provide testing to assess the stability of the model’s estimated relationships, for example:

* For statistical regression models, this involves regression coefficient stability testing and testing for structural breaks. Coefficient stability testing can be performed by repeatedly re-estimating the model on different subsets of the development sample (e.g., random sub-samples or samples representing different time periods covered by the dataset) as well as out-of-sample / out-of-time datasets. Values of regression coefficients and p-values across all samples are then assessed to evaluate the model stability.
* For machine learning models, because a comparison of model parameters is either impossible or impractical, testing of model stability generally involves a comparison of key performance statistics (e.g., K-S, AUC, Precision, Recall, F1, etc.) on different training and testing datasets. A common technique for assessing machine learning model’s stability and evaluating the risk of model overfitting is k-fold analysis. K-fold analysis should be performed in addition to testing of the model on the training, validation, out-of-sample, and out-of-time datasets.

Model Owner: xxxxxxx

### Back-testing

In addition to the model performance/fit testing documented in Section 3.3.2. Model Performance / Fit Testing, back-testing is highly beneficial and should be performed/documented for certain types of models. Back-testing is a class of testing techniques designed to assess the consistency of model predictions/estimations with the actual observed values, especially for different historical periods and over longer testing horizons.

These tests are designed to measure the accuracy of model performance over specified time periods. When documenting back-testing analyses, it is critically important to provide a detailed description of the test design including, for example:

* The design of the testing dataset includes the description of the time period, and information about any notable exclusions/inclusions that are inconsistent with the data used to develop the model.
* The logic for generating model predictions. For example, when back-testing a mortgage default model, the model developer would typically start with a particular historical portfolio snapshot and then use the model to generate predictions for each subsequent month/quarter without truing the model up using subsequent historical data.
* The source and nature of inputs and assumptions used in the back-test. For example, for a model that uses macroeconomic variables as inputs, the typical practice is to use actual historical values of such inputs during the back-test period (in order to isolate the error of the tested model from the error in the economic forecasts).

Use of graphical presentation of actual and predicted values is necessary in addition to any quantitative measures of model error (e.g., MAPE, MSE, etc.). This allows the model developer and reader to observe any areas of persistent model bias.

The developers should ensure that performance metrics and thresholds for acceptable performance are clearly stated and are aligned with the model’s business use. For example, for stress testing or CECL model designed to produce loss forecasts over a 2-year period, one of the error metrics should be based on the cumulative actual vs. predicted losses over a 2-year back-testing horizon.

Back-testing results should be accompanied by detailed narrative providing the model developers’ assessment of said results and their conclusions about any notable model biases or elevated error rates. Some such notable biases and performance issues may need to be noted as model weaknesses that must have associated risk mitigants.

Back-testing should be carried out for different populations. For example, when analyzing performance of residential or commercial mortgage loans, one should separately evaluate performance of the model on sub-populations that can be reasonably expected to have different behavioral characteristics. For example: different products, different vintages, or different segments of population by FICO score or by LTV or by another key risk driver.

Predictive models should also be back-tested over different economic environments, e.g., periods of stress vs. periods of economic growth. This is especially important for stress testing, CECL, and IFRS 9 models.

For vendor models, include the model owner’s assessment of the back- testing results provided by vendor (based on vendor’s data) and any associated risks. In addition, provide testing results on the Company’s internal data (or explain why it is not feasible).

In-time

Use this section for backtesting using the data from the same time period on which the model was estimated/trained.

Model Owner: xxxxxxx

Out-of-time

Use this section for backtesting using data from the time period different from the in-sample data.

Model Owner: xxxxxxx

### Model Explainability Testing

**For machine learning models**, provide sufficient information to understand the drivers of the model outputs and the directionality of their impacts. Use feature importance, Partial Dependency Plots, and a global interpretation method that explains the relationship between model inputs and outputs (e.g., SHAP feature importance, permutation-based feature importance, etc.)

For models that require generation of adverse action reason codes, testing of local interpretability using methods such as LIME is also required.

Advantages and disadvantages of the selected explainability testing methods should be discussed as well.

Model Owner: xxxxxxx

### Benchmarking

Compare model results with alternative results using other models and/or other data (if available). Describe the benchmark model or data in sufficient detail to enable an assessment of its value as a reference point. For example, a benchmark model that is also a formal Challenger model that has been independently validated (with a successful validation outcome) would be a stronger reference point than a benchmark model that may be available but that has not been extensively tested. Similarly, external peer data may be more relevant in a benchmark comparison than broader industry data. Provide a detailed narrative explaining the outcome of the comparison and any notable differences between the model outputs and benchmarks.

Model Owner: xxxxxxx

### Sensitivity Analysis

Quantify the impact on model outputs of changes in the value of model inputs and assumptions (e.g., economic inputs, tuning parameters, calculation rules, and scenarios). If the model design is such that the sensitivity of the model output to changes in an individual input would depend significantly on the value of one or more of the other inputs, the impact of simultaneous changes in inputs should also be evaluated.

Model Owner: xxxxxxx

### Stress Testing / Scenario Analysis

Quantify the impact on model outputs of stressed changes in the values of inputs, including scenarios that are outside the range of ordinary expectations.

For stress testing/CECL/IFRS 9 and other models dependent on economic scenarios, assess the model forecast across benign and stressful scenarios. When evaluating model forecasts under different economic scenarios, the forecasts should be compared to historical values during similar economic conditions (to the extent that such comparison is meaningful). Any notable differences should be explained and justified. For example, if a model produces drastically lower forecasts of losses under a severe stress scenario compared to the historical losses during the Great Recession, an explanation (e.g., notable improvements in the portfolio quality) should be provided and supported with quantitative analysis, where possible.

The forecasts should also be assessed for internal consistency. For example, do the base, adverse, and severely adverse forecasts reflect incremental macroeconomic stress, or, if not, are they consistent with the unique characteristics of the scenarios and business intuition?

For vendor models, stress testing/scenario analysis should be performed on the Company’s internal data. If not feasible, include the model owner’s assessment of the stress testing and scenario analysis provided by vendor (based on vendor’s data) and any associated risks.

Model Owner: xxxxxxx

### Other Testing

Describe other testing performed applicable to the selected modeling approach, **if any**.

Model Owner: xxxxxxx

### Overall Performance Assessment

Discuss overall conclusions on model performance based on the results of the testing described above.

Model Owner: xxxxxxx

### Need for Model Overlays

Document any proposed or implemented adjustments or overlays to the model outputs and their rationale. Describe the process for derivation and application of these overlays. Provide the impact by including model results with and without these overlays. Finally, outline the overlay review & challenge/approval process, including any Senior Management / Committee reviews and approval process if applicable, and the frequency of the overlay re-evaluation.

For vendor models, discuss the need for model tuning/dialing settings to better align model outputs to the Company’s internal outcomes.

Model Owner: xxxxxxx

# PRODUCTION PROCESS COMPLETENESS & ACCURACY

This section includes procedures and information related to model testing and usage following model development or vendor model acquisition.

**Reference Document List**

Please list all the documents referred to in this section.

|  |  |  |
| --- | --- | --- |
| **#** | **Reference Document Name** | **High Level Description and purpose of the Document** |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |

## Production Application Testing

Describe the testing for accuracy of implementation of the model into production systems.

### System Testing Approach and Results

The objective of model production application testing is to ensure that computational processes implementing model calculations:

* Are consistent with the documented model specifications produced as part of the model development process. This includes source data fields, data transformation rules, mathematical equations, assumption values, etc.
* Are consistent with the documented business / user requirements.
* Are mathematically accurate and complete.
* Have been reviewed for consistency with any applicable accounting/finance specifications (e.g., GAAP and/or accounting policy requirements), stress testing requirements, or any other applicable regulatory requirements.
* Are operationally stable, repeatable, and sustainable.
* Interface accurately with both upstream and downstream systems (where applicable).

For vendor models, the purpose of the production application testing is to ensure that the models are correctly implemented on the Bank’s systems—if on-premises production process is selected, or the vendor’s model production environment is correctly connected to the Bank’s production data environment—if a cloud-based production process is selected, that the Bank’s production data inputs are consistent with the model publisher’s input specifications, and that all applicable software patches and fixes have been applied.

Describe in detail the testing plan for the individual model’s production implementation and its integration within a larger system and the vendor’s model production environment, if applicable. Include User Accepting Testing cases and scenarios, expected outcomes, and the individuals responsible for executing the test cases.

Document the results of the UAT testing execution, and the associated log of issues and subsequent resolutions.

Model Owner: xxxxxxx

### User Acceptance Testing Approach and Results

Document the User Acceptance Testing approach, results, and sign-offs.

Model Owner: xxxxxxx

## Model Production Specifications

The following technical specifications should cover the end-to-end operation of the model, from data inputs and assumptions to final model reports. **To avoid duplication of information, some of the following sections may refer to earlier document sections instead of repeating the information.**

### Model Platform

Describe the technologies used for running the model, for example, Python, R, Excel, etc.

Model Owner: xxxxxxx

### Data and Process Flow Diagram

Provide a flow diagram showing data sources, inputs, quality assurance control points, intermediate results, outputs, and reports.

Model Owner: xxxxxxx

### Input Data Specifications

Provide a list of all inputs, including measurement units, a description of valid values or ranges (a full data dictionary should be attached in an appendix). Describe any data processing rules, such as filtering missing or invalid values infilling / overrides, substituting ceiling or floor values, data transformations, etc.

Model Owner: xxxxxxx

### Model Formulas / Algorithms

Describe detailed model formulas, algorithms, and numerical techniques, if possible.

Model Owner: xxxxxxx

### Model Parameters and Settings Values

Provide the values for all parameters and other input assumptions, including hyper-parameters for machine learning models.

For vendor models, specify values of user-selectable settings.

Model Owner: xxxxxxx

### Model Outputs

Provide a list of all model outputs, including expected values or ranges.

Model Owner: xxxxxxx

### Reports

Provide a list of all standard output files or reports and describe how they are used in the business.

Model Owner: xxxxxxx

## Operational Controls

Operational controls related to the model should be in place prior to the production deployment of the model.

### Model Access and Security

Access controls prevent unauthorized changes to the production code and unauthorized operation of the model in production. Describe who has “write access” to the model and can make changes to the underlying code of the model in development and in production, who has access to run the model in production, and who controls model access rights. If there is a formal access monitoring and review process in place, describe it here. Indicate whether any model files are password protected.

If there is no technical mechanism to prevent changes to the model in production (e.g., if the model is implemented using Python code), describe any checks performed to verify that no unauthorized changes have been made since the last approved update or use of the model (such as code comparisons).

Model Owner: xxxxxxx

### Production Deployment

Describe the production deployment process for the new model or changed model, including related controls.

Model Owner: xxxxxxx

### Model Usage Controls

Describe the controls related to model usage, such as verification of inputs (including reconciliation to the general ledger or other reference data, as applicable), confirmation of successful model execution (e.g., all input records were processed, output values are within valid ranges), completion of hand-offs to downstream users of the model’s outputs, etc.

Model Owner: xxxxxxx

### Model Backup

Provide the model backup procedures, including parties involved and frequency, and describe how the model owner has determined that the procedures are functioning correctly.

Model Owner: xxxxxxx

## Contingency Plans

### Disaster Recovery Plan

Provide a reference to the disaster recovery plan or describe the plan here.

Model Owner: xxxxxxx

### Business Continuity Plan

Provide a reference to the business continuity plan or describe the plan here. For a vendor model, provide the plan for how the model will be supported or replaced if the external vendor is no longer available to support the model or the vendor’s level of service is unsatisfactory.

Model Owner: xxxxxxx

## Operating Procedures / User’s Guide

Provide step-by-step procedures for running the model, which may include:

1. Input data extraction and preparation, including data cleaning and transformations.
2. Checking the correctness of input data.
3. Setting/updating/checking model settings, assumptions, and parameter values.
4. Checking the correctness of the settings, assumptions, and parameter values.
5. Initiating the processing component of the model.
6. Checking successful completion of the model execution.
7. Extracting model outputs.
8. Checking that model outputs are valid.
9. Producing standard reports.
10. Distributing standard reports.

Note: if there is a separate operating procedural document (or User’s Guide), please list the document name below and share the document with MRM.

Model Owner: xxxxxxx

# ONGOING MODEL GOVERNANCE & OUTCOME ANALYSIS

**Reference Document List**

Please list all the documents referred to in this section.

|  |  |  |
| --- | --- | --- |
| **#** | **Reference Document Name** | **High Level Description and purpose of the Document** |
| 1 |  |  |
| 2 |  |  |
| 3 |  |  |

## Ongoing Risk & Performance Monitoring Plan

**Part 1** - provide an overview of the performance monitoring process, including:

1. Frequency of monitoring activities.
2. Titles/positions of individuals/teams responsible for executing performance monitoring analyses.
3. Individuals responsible for evaluating the resulting reports and documenting conclusions.
4. Stakeholders responsible for reviewing the performance reports and initiating required actions in the event that new risks or performance weaknesses are detected.

**Part 2** - provide the details of the **ongoing risk and performance monitoring plan (together, ongoing monitoring plan)** for this model. Ongoing monitoring plans should generally cover the following two types of periodic monitoring activities:

1. Model Risk Monitoring – Reassessment of the model’s risk profile. This includes but is not limited to reassessment of model weaknesses and limitations, as well as the associated risk mitigants in light of any changes in the model use, Company’s strategy, market conditions, and regulatory environment, among other things.
2. Model Performance Monitoring – Analysis of the model’s **predictive performance** and **identification of emerging model performance weakness**.

Specifically, for Model Performance Monitoring design, it is expected that all models should have some type of outcomes-based performance monitoring process in place to evaluate whether the model is meetings its designed objectives. The Model Owners must specify, as appropriate and feasible for the specific model and its individual uses, detailed plans to monitor model performance through **some combination of the following** four methods:

* Comparison of predicted outcomes to actual values (i.e., back-testing).
* Benchmarking model outputs against comparable external data points, such as observable market information, or outputs of alternative models.
* Analysis of sensitivity of model outputs to variations in model inputs, parameters, and assumptions.
* Stress testing of model predictions to extreme changes in model inputs and assumptions.

The Model Owner should define performance thresholds which, if breached, would require the Model Owner to take corresponding actions. Performance thresholds may be set based on business unit policies or procedures, judgmentally, or based on statistical methodology utilizing model performance over the development sample. In all cases, the approach for setting performance thresholds should be established during development and documented in this section.

**Guidelines** for Risk & Performance Monitoring Plan details:

* Risk Monitoring Plan Details: The risk monitoring plan should list the internal and external factors that should be considered when evaluating model risks. This may include, as applicable:
  + - * Changes in the model use.
      * Changes in the portfolio composition or characteristics of the portfolio/asset/liability/transactions to which the model is being applied.
      * Changes in the Company's strategy.
      * Industry and economic environment changes.
      * Regulatory environment changes.
      * New regulatory findings, independent model validation findings, internal audit findings, external audit findings etc. The plan should include a list of internal and external stakeholders, groups, and committees that may identify, either directly or indirectly, model-related risks through their own “ordinary course of business” activities. It is expected that the Model Owner will establish and maintain periodic communications with these stakeholders to monitor emerging risks.
    - Performance Monitoring Plan Details: The performance monitoring plan should include:
* The source(s) of data used in the performance monitoring process.
* The list of key performance metrics that will be calculated and reported along with their technical specifications.
* Description of the performance analysis that will be performed consistent with the requirements.
* Acceptable performance thresholds for each key metric, if applicable. If a specific threshold is not defined, the Model Owners should document the justification for the lack of threshold. The Model Owners’ rationale for selecting particular performance thresholds must be adequately documented. If, as is sometimes the case, an oversight committee is required by the Business Unit/Line of Business to approve model performance thresholds, then this fact must be reflected in the monitoring plan and the Model Owners must retain evidence of such approvals. Finally, the frequency of the re-evaluation of the performance thresholds should be documented.
* Procedures for communicating and escalating performance issues to appropriate stakeholders (committees, upper management, etc.).
* Procedures for responding to performance threshold breaches.
* The list of stakeholders (individuals and committees) responsible for the review of the risk and performance reports.

Part 1 – Overview

|  |  |
| --- | --- |
| Frequency of monitoring activities (e.g., monthly, quarterly, etc.) |  |
| Titles/positions of individuals/teams responsible for executing performance monitoring analyses |  |
| Individuals responsible for evaluating the resulting reports and documenting conclusions |  |
| Stakeholders responsible for reviewing the performance reports and initiating required actions in the event that new risks or performance weaknesses are detected |  |

Part 2 – Risk & Performance Monitoring Plan

Model Risk Monitoring Plan Details:

Model Owner: xxxxxxxx

Model Performance Monitoring Plan Details:

Model Owner: xxxxxxxx

## Model Approval and Change Management Process

In this section, discuss the aspects of the model approval and change management process that are specific to this model.

### Model Approval Process

Provide the names of the individuals (or a committee) involved in the approval process for this model.

Model Owner: xxxxxxx

### Model Change Log

Provide a reference to the model Change Log. Please refer to the Bank’s 1st Line Model Risk Management Guidelines (MRM-PnP05), the MRM Procedure (MRM-PnP02), and Model Change Log Template v01.docx for detailed requirements.

Model Owner: xxxxxxx

# APPENDICES

## Appendix A

List and describe references to additional model-related files that have not already been referenced in the Template.

1. DocName\_1.pdf (doc, txt, xls, etc.)

Description: xxx

1. …

Model Owner: xxxxxxx

## Appendix B

For vendor models, provide high level description of the vendor company background, qualifications, and services provided, especially relating to EWB’s purchase. In addition, please reference MRM procedure MRM-PnP04, MRM-PnP04 EWBC MRM Vendor Model Onboarding Process v01.pdf, for detailed onboarding and documentation requirements.

Model Owner: xxxxxxx