SAS® Credit Risk Management for Banking enables the user to accurately assess the risk of potential credit losses both on the counterparty level and on the portfolio level. The user can calculate regulatory capital with respect to all three Basel II approaches (Standardized, IRB Foundation, and IRB Advanced), carry out scenarios and stress-testing, calculate current and potential risk exposures, improve capital allocation and maximize the return from risk management investments. It facilitates the meeting of reporting and risk disclosure requirements of regulators and investors. On top of that, the SAS solution allows the modeling of economic capital in a flexible framework.

Below the SAS solution is described in more detail, including various aspects such as data readiness, data management, internal rating, regulatory and beyond Basel II calculations, disclosure, system architecture, system transparency and audit.

1️⃣ Data readiness & data model

The SAS® Banking Intelligence Data Model (BIS DDS) supports both credit scoring and credit portfolio risk management for faster implementation. The BIS DDS includes loading of an organization’s data, such as position data (transactions), risk factor data, risk components data, and customer behavioral data, and supports a reporting framework for management and supervisory reporting.

**Benefits:**
- Data model is calibrated to reflect bank-specific data and Basel II data requirements.
- Ensures successful data mapping process to the existing source systems.
- Basis to assess data readiness, assess to which extent the bank’s core systems can deliver the required data, and identify potential data gaps.
- The data model supports extendibility to other solutions, and allows the incorporation of extensions and changes to the data model and to the referring application rapidly and efficiently.
- Pre-coded ETL Bridge to load data from the SAS BIS DDS representation into the SAS solution data mart.

2️⃣ Data management

Consistent, accurate and reliable data is required in order to achieve best practice in credit risk management. A bank can adopt this based on SAS Warehousing technology that provides best of breed data management capabilities including quality checks, data historization, and data cleansing. Based on SAS methodology for collecting and sharing data, the data is reusable and can be incorporated into the overall data architecture and
management processes. Coordinating data among risk segments and other enterprise data is a best practice a bank can adopt based on SAS.

3 Internal rating

SAS® Credit Scoring allows the development, deployment and monitoring of scoring models. You can build homogenous customer segments with respect to their likeliness to default (rating segments, rating pools) and to determine an average probability of default (PD) per rating class / pool based on a history of customer behavioral data. In addition you can develop loss-given-default models (LGD), and monitor model performance, including monitoring of score performance, migration analysis, vintage analysis, and approval analysis.

Benefits:
- The SAS In-House Scorecard Development is fast, affordable, flexible, accurate, secure, and compliant and increases personal skills and the corporate knowledge base.

<table>
<thead>
<tr>
<th>SAS Credit Scoring - Credit Scoring Model Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Development of scoring models that assign individual PDs to counterparties:</td>
</tr>
<tr>
<td>- Scorecard development: automatic and interactive variable grouping and variable selection, stepwise logistic regression, scorepoint scaling</td>
</tr>
<tr>
<td>- Scorecard assessment reports: trade-off charts, cost-optimal cut-off point, separation of default/non-default, concentration curve, KS statistic, area under ROC chart, Gini Coefficient</td>
</tr>
<tr>
<td>- Tree model development (for interaction detection and segment definition for scorecard development or as a stand-alone scoring model)</td>
</tr>
<tr>
<td>- Neural networks (Multi-Layered Perceptrons, Radial Basis Functions)</td>
</tr>
<tr>
<td>- Documentation through achievable process flow diagrams and html process flow reports</td>
</tr>
<tr>
<td>- Binning of the individual PDs to define rating classes / pools</td>
</tr>
<tr>
<td>- Development of LGD models</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS Credit Scoring - Model Deployment (may require additional customizations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Assignment of a rating class / pool to each counterparty</td>
</tr>
<tr>
<td>- Determination of an average PD per rating class / pool</td>
</tr>
<tr>
<td>- Determination of average LDGs and CCFs per rating class / pool</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS Credit Scoring - Model Performance Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Monitoring the Score Distribution</td>
</tr>
<tr>
<td>- Monitoring Inputs</td>
</tr>
<tr>
<td>- Monitoring Score Performance</td>
</tr>
<tr>
<td>- Comparison of actual and predicted default rates</td>
</tr>
<tr>
<td>- Monitoring Losses</td>
</tr>
<tr>
<td>- Migration analysis &amp; rating grade migration reports</td>
</tr>
<tr>
<td>- Vintage analysis &amp; monitoring of current delinquency status and delinquency rates (including a breakdown by vintage period)</td>
</tr>
<tr>
<td>- Approval Analysis: Monitoring of the rating-based lending approval process</td>
</tr>
<tr>
<td>- Override frequencies</td>
</tr>
<tr>
<td>- Tracking of individual override cases</td>
</tr>
</tbody>
</table>

4 Regulatory calculations

SAS® Credit Portfolio Risk analysis delivers pre-configured regulatory capital calculation (based on risk-weighted assets) supporting the generic rules of the Basel II Capital
Accord and CADIII for all three approaches of credit risk (Standardized, IRB Foundation, IRB Advanced). This is a basis for Basel II compliance, and is integrated with scenario analysis, stress-testing and an optimized cover allocation algorithm; the underlying risk engine of SAS Credit Portfolio Risk analysis is SAS® Risk Dimensions. Basel II calculations are pre-configured covering more than 40 financial product types including loans, deposits, accounts, credit risk mitigants, securitization, securities, repurchase agreements, forwards and swaps. The SAS system delivers a standardized workflow to calculate regulatory capital at the individual transaction level, and at the same time aggregated by categories such as asset-class and product type, and overall aggregated figures. This SAS workflow includes:

- Pre-configuration of Basel parameters as defined in the accord (standardized risk weights, LGDs, haircuts, CCFs, add-ons, pre-configured continuous risk weight function, options to choose overall approach and Basel II options on a more granular level)
- Mark-to-market evaluation (e.g. for financial collateral), determination of exposure-at-default and effective maturity
- Structuring the portfolio in the different asset categories and sub-categories and mapping to the Basel II categories
- Determination of the risk weights
- Treatment of credit risk mitigants
- Reporting framework (see also disclosure)

### SAS Credit Portfolio Analysis – Basel II Regulatory Capital Approaches

- Standardized approach
- IRB Foundation approach
- IRB Advanced approach

### SAS Credit Portfolio Analysis – Pre-configured Basel II Workflow

The pre-configured SAS Basel II workflow includes:

- Data preparation and risk environment pre-definition
- Portfolio evaluation (mark-to-market or stress-test)
- Risk Component Calculation (Exposure-at-default, Risk Weights, LGD adjustments)
- Credit Risk Mitigant allocation (incl. optional optimized cover allocation)
- Recognition of Provisions
- Calculation of Risk-Weighted Assets & Regulatory Capital
- Reporting of results

### SAS Credit Portfolio Analysis – Stress Testing on Regulatory Capital

Two major risk factor groups:

- Market risk factors, e.g., interest rates, FX rates, and security prices, etc. They mainly impact on the market value of the exposures and collateral.
- Credit risk factors incl. the Basel II Risk Components, e.g., PDs, LGDs, Credit Conversion Factors, rating grades, credit spreads, etc.

### SAS Credit Portfolio Analysis – Coverage of Exposure types for Reg. Capital Calculation under IRB

- Sovereign
- Bank
- Corporate
  - Corporate lending
  - SME (small and medium sized enterprises)
  - Specialized lending: High volatility commercial real estate (HVCRE): Except IRB approach for HVCRE.
Retail
- Exposures secured by residential mortgages
- Qualifying revolving retail exposures (ORRE)
- Other non-mortgage exposures also known as “other retail” (Other retail lending includes e.g.
credit cards): Most are supported

Equity: Simple risk weight method is supported. PD/LGD approach is also supported except the
hedging positions (not relevant to most banks, but will impact a limited number of wholesale banks)

Securitization

SAS Credit Portfolio Analysis – Financial product coverage of pre-configured Basel II
calculations

<table>
<thead>
<tr>
<th>Loans &amp; Deposits</th>
<th>Credit Risk Mitigants</th>
<th>Securitization</th>
<th>Forwards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Mortgages</td>
<td>Receivables</td>
<td>Residential mortgage backed securities (RMBS)</td>
<td>Forward Rate Agreement</td>
</tr>
<tr>
<td>Revolving Retail</td>
<td>Physical Collateral</td>
<td>Commercial mortgage backed securities (CMBS)</td>
<td>Foreign Exchange Forward</td>
</tr>
<tr>
<td>Credit lines</td>
<td>Cash used as Financial Collateral</td>
<td>Collateralized Debt Obligation (CDO)</td>
<td>Repo</td>
</tr>
<tr>
<td>Credit Facility</td>
<td>Securities used as Financial Collateral</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advance (with and without explicit cash flow)</td>
<td>Guarantee</td>
<td>Other Asset backed securities (ABS)</td>
<td></td>
</tr>
<tr>
<td>Commercial Loan (with and without explicit cash flow)</td>
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<td></td>
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<tr>
<td>Customer Loan</td>
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<tr>
<td>Day-to-Day Deposit</td>
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<tr>
<td>Callable Deposit</td>
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<tr>
<td>Deposit with 1 CF and no intermediate payments</td>
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<tr>
<td>Callable Placement</td>
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<tr>
<td>Day-to-Day Placement</td>
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<tr>
<td>Placement with 1 CF and no intermediate payments</td>
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<tr>
<td>Term deposit</td>
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</tbody>
</table>

SAS Credit Portfolio Analysis – Basel II Credit Risk Mitigant Treatment

Netting
- Collateralized transactions
  - Simple approach
    - Comprehensive approach
      - Supervisory haircuts
      - Own estimates of haircuts – yes, with customization
      - VaR model – yes, with customization
  - Substitution
  - First and second to default – yes, with customization

Beyond Basel II calculations
The risk engine of SAS® Credit Risk Management (SAS® Risk Dimensions) is designed
to be highly flexible and offers in depth modeling capabilities to build a propriety cutting
dge economic capital model. All major methodologies including structural model
approach (such as KMV), behavioral model approach (such as CreditMetrics), actuarial
approach (such as CreditRisk+), and internal model/simulation based approach can be
implemented. In particular, economic capital models can include modeling of credit
migrations, linking of macro-economic and industry factors, and allow the consistent
combining and integrating of market risk and credit risk. Thus the user can develop a
consistent capital reserve methodology across all portfolios. In addition to capital
allocation, the SAS based credit risk information can be used for pricing decisions, product assessment and to value overall client relationships.

Benefits:

- Ability to leverage beyond Basel II analytics in the same framework as regulatory Basel II calculations – allowing the leveraging of the initial investment to a new level, in contrast to several other vendors who propose additional full modules.
- SAS offers flexibility to grow and anticipate future requirements and evolutions; for example, in the future it is expected that regulations will allow for usage of internal economic capital models to compute credit risk regulatory capital.
- Proprietary credit risk models can be incorporated.

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Capital allocation methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Regulatory Capital according to Final Basel II Capital Accord / CADIII</td>
</tr>
<tr>
<td>• Internal modeling of Economic Capital</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Scenario Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two different types of Scenario Analysis:</td>
</tr>
<tr>
<td>• “What-if” Scenario Analysis: One-off shot in terms of one risk factor scenario → Result: Value of target variable (S) with respect to the extreme “what-if” situation</td>
</tr>
<tr>
<td>• Scenario Simulation: Large number of risk factor scenarios generated → Results include, in addition to above, Quantiles of target variable (S) distribution</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Interactive Scenario Builder</th>
</tr>
</thead>
<tbody>
<tr>
<td>• GUI to build scenarios including parallel shifts and complex changes for risk factor groups like interest rate curves</td>
</tr>
<tr>
<td>• The interactive Scenario Builder automatically generates the referring scenario analysis including batch code</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Coverage of Financial Instrument pricing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through open integration with external pricing functions, there is no limitation in product coverage with respect to pricing, including complex credit derivatives, such as credit default swaps, n-th to default basket swaps, and securitization. This requires customization.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Economic Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Highly flexible modeling framework to cover both current requirements and anticipate future methodologies for Credit Risk Mgmt</td>
</tr>
<tr>
<td>• All major Credit-Value-at-Risk methodologies can be implemented like Credit+, KMV, CreditMetrics, CreditPlusView, Internal Models/simulation-based approach.</td>
</tr>
<tr>
<td>• No pre-coded CVaR Model</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Stress Testing on Economic Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relevant risk factors depend on type of economic capital model:</td>
</tr>
<tr>
<td>• Same as for Basel II stress tests</td>
</tr>
<tr>
<td>• In addition, scenarios of macro-economic factors like inflation, real estate prices, unemployment rate, living costs, parameters describing the economic cycle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Simulation engine</th>
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</thead>
<tbody>
<tr>
<td>• Historical Simulation</td>
</tr>
<tr>
<td>Two types of Monte Carlo Simulations:</td>
</tr>
<tr>
<td>• Covariance-based Monte Carlo simulation</td>
</tr>
<tr>
<td>- Risk factors are assumed to be distributed normal/lognormal</td>
</tr>
<tr>
<td>- Correlations/covariances are entered into the simulation engine through a covariance matrix</td>
</tr>
<tr>
<td>• Model-based Monte Carlo simulation</td>
</tr>
<tr>
<td>- Individual risk factor modeling applying individual distribution functions</td>
</tr>
<tr>
<td>- Different types of models can be combined within one simulation</td>
</tr>
<tr>
<td>- Correlations between risk factors are treated correctly (copula framework)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SAS® Credit Portfolio Analysis – Additional beyond Basel II analytics</th>
</tr>
</thead>
</table>
- Optimized credit cover allocation (with respect to Regulatory Capital calculation)
- Multi-level Netting
- Transition Matrix Functions
- Portfolio Optimization
- Current Exposure
- Potential future Exposure
- RAROC
- TWR – Time weighted returns
- Cash flow functionality for ALM and effective maturity calculation

**SAS® Credit Portfolio Analysis – Standard Graphical Reports**
Interactive aggregation and decomposition of all results including non additive at-risk measures through configurable drill-down variable (cross-classifications):
- Simulation density plot: Profit&Loss probability distribution including distribution properties like CVaR and economic capital
- Key risk indicator reports: Identification of risk factors which contribute most to the current risk exposure (Shannon-information measures)
- Efficient Frontier Graph
- Gap Analysis graphs for cash flow analysis
- Profit/Loss Curves & Surfaces
- Basel II Regulatory Reporting (see SAS® Credit Risk Studio)

**SAS® Credit Portfolio Analysis – Credit Scoring Interface**
- Interface to Enterprise Miner Model Repository
- Feed PDs from SAS® Credit Scoring to SAS® Risk Dimensions as risk factors
- Framework to leverage scoring models that have been developed inside Credit Scoring within a Risk Dimensions simulation; this allows, e.g., modeling of rating migrations within an Economic Capital calculation – this may require customization.

**Disclosure**
SAS® Credit Risk Studio includes management and supervisory reporting templates, and allows sharing reports across the organization through a web portal. The SAS Credit Risk Studio supports online aggregation and decomposition by means of OLAP technology; the reporting templates include:
- Unweighted exposure
- Risk weighted assets
- Risk concentrations
- Regulatory capital charges
- Credit quality such as PDs
- 90-days-past due reports

**Benefits:**
✓ Meet Pillar I, Pillar II, and Pillar III (Disclosure) requirements based on a single framework.

**SAS® Credit Risk Studio**
Interactive aggregation and decomposition of all results, including non additive at-risk measures through configurable drill-down variable (cross-classifications)

**Credit Quality Reports** (referring to the PDs and LGDs applied in the regulatory capital calculation)
- Average PD by cross-classifications
- Average LGD by cross-classifications
- 90 day past due by cross-classifications

**Regulatory Capital**
- Regulatory Capital requirement by cross-classifications
- Firm wide Regulatory Capital history

**Exposures**
- EAD by cross-classifications
- Firm-wide EAD history
- Portfolio MTM by cross-classifications
- Firm-wide Portfolio MTM history

**Risk Contributions by Cross-Class**
- Capital requirement contribution by cross-classifications
- EAD contribution by cross-classifications

© System architecture

SAS® Credit Risk Management 4.1 – System Architecture

SAS® Credit Risk Management is integrated with the SAS® 9 Business Intelligence Platform scalable to enterprise-wide level; this includes integration with SAS® Foundation Services, SAS® Metadata Server, SAS® OLAP Server, SAS® Stored Process Server, SAS® Workspace Server, and Job Scheduler.

Efficient usability and manageability of SAS Credit Risk Management is incorporated through standard interfaces tailored to different user roles (see graph above):

⇒ **SAS Credit Risk Studio interface**: Web-based client front-end for information consumers, decision makers, power users, and business analysts

⇒ **SAS Enterprise Miner Credit Scoring interface**: Client interface for power users and scoring analysts
SAS Risk Dimensions interface: User interface for power users and credit risk analysts; configurable through graphical and batch interface; server-based risk services for production run computation; client interface for ad-hoc analytics. SAS Risk Dimensions incorporates the concept of inheritance to provide risk analysts with their own SAS Risk Dimensions environments which are identical to the server-based master set-up, but any user-specific modifications reside within their local inherited environment. This is part of the multi-user and multi-project capabilities of SAS Credit Risk Management, and allows for an automated multi-user and multi-project application to avoid interference with other users.

SAS ETL Studio interface: Client interface to manage data and processes (such as batch job processing to configure and run SAS Risk Dimensions) for system administrators and IT.

SAS Management Console interface: Client interface for system administrators and IT providing a single point of control for managing enterprise technology including servers, applications, security, libraries and metadata, across multiple platforms.

Audit & System transparency
The Basel II requirements generally refer to maintaining appropriate internal controls and auditability for data management, parameterization, quantitative modeling processes, and the overall process to calculate regulatory capital. From a technology perspective, SAS Credit Risk Management facilitates internal control and auditability in many ways, mainly through the basic functionality of SAS ETL Studio, SAS Credit Scoring, and SAS Risk Dimensions. Here are several examples:

Examples on Data Management:
- Impact & reverse impact analysis of data flows
- Central Option setting
- Data management flows are self-documenting in the sense that while building the data flows the resulting flows are represented graphically for visual documentation through a specific GUI (ETL Studio GUI) – this is based on metadata
- SAS ETL Studio, the graphical ETL design environment, furthermore supports check-in/check-out capabilities that allow multiple users to work concurrently, including support for developing and testing in their own playpen environments. This functionality essentially represents the user ‘signing off’ on the dataset before it goes into production.

SAS Enterprise Miner Credit Scoring:
- Utilizes ‘model packages’ stored in a model repository. A ‘model package’ is an archive of the model environment which stores all information about the modeling analysis including data, metadata, a description of the modeling flow and the resulting model itself. This provides an audit trail (through metadata) that shows that someone has approved a model to go into production, and further enables changes to be traced (time stamp, name of analyst who changes the model, etc.).
- Credit Scoring model flows are self-documenting in the sense that the resulting flow of building a model process is represented graphically for
visual documentation through the Enterprise Miner GUI, which is based on metadata.

• **SAS Risk Dimensions:**
  - Portfolio Models (such as regulatory or economic capital models) which are set-up by applying to the risk engine of SAS Credit Risk Mgmt can be versioned through SAS SCM (Source Control Manager) or a third party tool
  - Customizations of the risk engine can be applied by means SAS batch scripts; the batch scripts can be versioned through the SAS SCM (Source Control Manager)
  - Portfolio models & users’ customization are automatically documented visually through a specific graphical user interface (Risk Dimensions GUI)
  - The users can set-up graphical process flows in SAS ETL Studio which run the SAS Risk Dimensions batch code in a transparent and auditable way.

• Audit and System Transparency supported in addition by core SAS® 9 technology, such as:
  - SAS Management Console
  - SAS Metadata Server
  - SAS Enterprise Miner Repository Manager
  - SAS Stored Process Server

• The SAS Metadata Server supports saving information about changes to metadata in a set of audit files

• **SAS Management Console**
  - Configure users and groups
  - Set security on who can do what and who can access the application
  - Used to manage ALL of the SAS platform
  - Single point of SAS administration

**Benefits:**
- System transparency for auditors and supervisors

---

**⪞ Technology**

**SAS Credit Risk Studio Technology**
- Java Server pages based on SAS Information Delivery Portal and SAS Web Report Studio

**Technology for Process management**
- SAS ETL Studio

**Integration with legacy systems**
- SAS Solution easily integrates with legacy systems and third party data management systems (ACCESS to ORACLE, SAP, SAP-BW, DB2, Sybase, PC-Files, OLEDB, just to list a few)

**SAS Release dependency**
- SAS9.1.3 Service Pack 2

**Platform Availability**
- **SAS Credit Risk Management Server Component**
  - Windows based platforms
    - Windows 32 bit
    - Windows 64 bit
  - Linux 32 bit
  - UNIX platforms
- Solaris 64 bit
- HP 64 bit
- AIX 64 bit
- Tru64™ UNIX®

**SAS Credit Risk Management Client Components**
- **SAS Credit Risk Studio**: Windows 32 bit, Solaris 64 bit, R64, HP 64 bit
- **SAS Web Report Studio 2.1**: Windows 32 bit, Solaris 64 bit, R64, H6I
- **SAS ETL Studio Client**: Windows 32 bit
- **SAS Enterprise Miner Client**: Windows 32 bit, Solaris 64 bit, R64, H6I

**Java Application Server**
- Apache/Jakarta Tomcat 4.1
- BEA WebLogic 8.1
- IBM Websphere 5

**Language of Front End**
- English

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**Acronyms - Business terms**
- ALM – Asset liability management
- CCF – Credit conversion factors
- CF – Cash flow
- CP3 – Third Consultative Paper of the New Basel Capital Accord
- CRM – Credit Risk Mitigant
- EAM – Exposure at default
- IRB – Internal Ratings based approach
- LGD – Loss given default
- MTM – Mark-to-market
- PD – Probability of default
- RWA – Risk Weighted Assets
- VaR – Value-at-Risk

**Acronyms - Technology terms**
- BIS – Banking Intelligence Solutions
- DDS – Detailed Data Mart
- EM – SAS® Enterprise Miner™
- ETL – Extract Transform Load
- GUI – Graphical user interface
- RD – SAS® Risk Dimensions
- ROC – Receiver Operator Curve