Model Lifecycle: From Development to Validation Process

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Agenda

1. Modelling Approaches
2. Model Management
3. Model Validation
Modelling Approaches
Portfolio segmentation

Review organizations' business structures, credit risk profiles, and relevant portfolios in order to determine:

» Portfolio structure
» Industry coverage and concentrations
» Data availability across different industry segments.
» Alignment of Risk Drivers
» Materiality of each segment (Exposure and number of obligors)
» Pros and Cons of each modelling approach per segment

Provide recommendations for ideal credit risk framework in line with client business requirements.

Typical project structure

1. Initial portfolio review and segmentation
2. Conduct rating methodology mapping to client’s portfolio
3. Produce recommendations on proposed scorecards
4. Propose Development & Calibration methodology and number of Models/Segments to be developed/Calibrated
PD modelling approach: driven by data availability

The approach to PD modelling depends on the amount of existing data in the organization's respective portfolio:

- **No data availability**
  - Off-the-shelf
  - Localization approach

- **Some data availability**
  - Verification Approach
  - Shadow Rating Approach

- **Large historical dataset available**
  - Statistical Approach

**Data Availability:** The two key elements are number of obligors and number of defaults in the past (for example over the last 5 years) per relevant portfolio.

**IRB Accelerator:** The use of an off the shelf model as for Example RiskCalc as the starting point can reduce the Development Timelines and increase the statistical robustness of the final model.
Verification approach overview

Moody’s alternative to the Statistical Approach for low-default portfolios

**STEP 01**

**Scorecard Design**
Design initial model based on the expertise and judgment of bank’s credit professionals and Moody’s
Leverage Moody’s rating methodologies for factor selection
Moody’s provide expertise on rating model design and feedback on the benefits and drawbacks of various approaches
The collaborative process ensures understanding of your objectives, history and portfolio

**STEP 02**

**Single Factor Analysis**
Based on an initial data collection, all inputs, Moody’s will analyze the following dimensions:
- Factor Distribution, Information Entropy, Rank Ordering, Factor Correlation, PD relationship, Predictive Power
- Based on expert rank ordering and benchmark ratings

**STEP 03**

**Weight Optimisation**
Genetic Algorithm: which performs a search to find the combination of factor weights for highest model performance
Tightening of the search space results with additional trade-off in model performance
The approach provides the client with the opportunity to incorporate best business practices and knowledge in the optimisation process integrating empirical modelling with expert judgment

**STEP 04**

**Mapping Optimisation**
Mapping Optimization is the process of mapping the scorecard model output (Score per client) to expert grades and associated PDs
This mapping process involves mathematical optimisation and manual adjustments that will ultimately minimise differences between the scorecard with client expert judgement-based ratings while ensuring a scorecard average PD equal to the Central Default Tendency

**STEP 05**

**Reliability tests and Model Documentation**
Bootstrapping is employed to leverage available data in an effort to reduce dependency on the original sample dataset and define confidence intervals to assess the consistency of the model.
A comprehensive report outlining the core methodology and results, and an Excel-based scorecard that the client can use in making credit decisions.
Verification Approach - Custom Project Finance PD for IRB

Case Study

Client Situation

» The client is a major Global Bank with a Project Finance Portfolio in EMEA, Americas and Asia
» The client wanted to evolve from Slotting Criteria expert based scorecard into an Advance IRB model
» The rationale for the decision was to increase the IRB coverage of the portfolio and reduce the capital spending in the segment
» Moody’s suggested the Verification Approach, due to the lack of past default information (i.e. less than 20), in combination with the use of Moody’s Project Finance Consortium data

Solution Provided / Key Highlights

» Development of 5 scorecards to cover the segment, following a segmentation analysis, with final deliverables including model documentation, prototype and development codes.
» Supported the institution throughout the internal validation process and the final outcome was a PRA approval for capital calculations.

Illustrative Output

Analytical Approach

Workshop

Review of the client portfolio to understand the key industries and size distribution
Mapping of industries from the client portfolio to Moody’s Investors Services rating methodologies to understand the key risk drivers relevant for the client portfolio
Discussion of factors to include in scorecards

Single Factor Analysis

Discussion and selection of Overlay Factors
Balancing of factors and initial weight assessment by expert judgment

Weight Optimisation

Optimising the scorecards by maximising alignment between scorecard result and benchmark ratings
Use of external ratings to help determine the benchmark ratings

Calibration

Definition of Central Default Tendency taking into account Consortium Default Rate information as well as internal
Alignment with the expert based benchmarks

Qualitative Section

Quantitative Section

Notching Factors

Example

<table>
<thead>
<tr>
<th>Industry</th>
<th>Consortium Industry split</th>
<th>Client Industry split</th>
<th>Consortium Default Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry 1</td>
<td>40%</td>
<td>25%</td>
<td>2.15%</td>
</tr>
<tr>
<td>Industry 2</td>
<td>32%</td>
<td>42%</td>
<td>1.49%</td>
</tr>
<tr>
<td>Industry 3</td>
<td>28%</td>
<td>33%</td>
<td>0.63%</td>
</tr>
</tbody>
</table>

Weighted CR = 1.51%
Weighted CR = 1.36%

Notch Differences

Number of Firms: 10

Construction period: 33%
Operations period: 67%
Shadow Rating Approach Overview

- For portfolios where external ratings are available, as for example, Insurance, Banks, Sovereigns.

Key Characteristics of approach:
- External Rating used as target variable.
- Use of Historical information matching the rating time span.
- Replication of rating agency but allows for greater control of final model.

Sample Definition:
- Representative sample from Moody’s Default and Recovery Database.

PD estimation:
- Determination of appropriate PD for each rating class.
- Cohort or Duration Approach.

Data collection and Review:
- Collection of historical financial-economic information.

Single Factor Analysis:
- Factor Transformation.
- Position Analysis.
- Alignment with external rating.
- Factor correlation.

Model Estimation:
- Linear Regression.
- Exhaustive Search.
- Adherence to statistical requirements (VIF and significance).

Calibration and Validation:
- Tranching.
- Incorporation of group and sovereign support.
- Bootstrapping.

East Africa Conference
Internal Rating Shadow Rating Approach / PD Model Development for Sovereign Counterparts
Case Study 4

Client Situation

» The client is an European Insurance Company
» The client wanted to develop a customized Sovereign Probability of Default (PD) model for developed countries
» The model is intended to assess the creditworthiness of sovereign governments as the client holds debt issues by this government
» As observed, sovereign defaults are very limited, especially for developed economies, shadow rating approach (SRA) was followed to leverage External Credit Agency (e.g. Moody’s) information

Analytical Approach

Data Collection
» Discuss and finalize with client key data requirements for sovereigns (External Ratings, Historical Financials, Quantitative indices e.g. WGI Government Effectiveness Index)
» In the SRA, PD is attached to each country. For this a transition matrix was estimated using Moody’s DRD data

Data Preparation
» Leverage all rated counterparts including sovereigns in DRD, instead of using only sovereigns, to avoid small sample bias
» Attach PD to each rating class using duration based migration matrix estimation method

Model Development
» Single factor analysis: assess each factor e.g. factor transformation, alignment with external ratings, PD relationship, factor correlations
» Multi-factor analysis: Missing value treatment, linear regression between log(PD) and transformed factors
» Model selection: High Roq, high alignment with ratings, correct sign of coefficients

Validation and Calibration
» Bootstrap to assess robustness of coefficients
» Validate model on crisis period i.e. 2009-2012
» Piecewise linear regression between model output and log(PD) to best align the predicted ratings with external ratings
» Compare model predicted ratings with Moody’s ratings for the country of issuer

Solution Provided/ Key Highlights

» A PD model prototype in MS Excel for estimating PDs and ratings and detail model development report documentation
» The model comprises of factors covering different broad categories e.g. Economic strength, Fiscal strength, Institutional strength, and Susceptibility of event risk
» Model covers key financial factors e.g. Terms of Trade, Average Real GDP Growth t-4 to t, Total Economy Financial Net Worth/GDP (%), Inflation Volatility t-4 to t, and key qualitative indices e.g. WGI Global Competitiveness Index

Illustrative Output

<table>
<thead>
<tr>
<th>Year</th>
<th>Moody’s rating</th>
<th>Model rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>Aa2</td>
<td>Aa2</td>
</tr>
<tr>
<td>2003</td>
<td>Aa2</td>
<td>Aa2</td>
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<td>Aa2</td>
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<td>2006</td>
<td>Aa2</td>
<td>Aa1</td>
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<tr>
<td>2007</td>
<td>Aa2</td>
<td>Aa1</td>
</tr>
<tr>
<td>2008</td>
<td>Aa2</td>
<td>Aa1</td>
</tr>
</tbody>
</table>
Statistical approach: RiskCalc Emerging Markets Model

A RiskCalc model intended to be used on all the Emerging Markets where there is currently no RiskCalc country model

01
Built with data from more than 20 Emerging Markets, using both public and private firm data. Sample is constructed in a way to mitigate the domination from any single country

02
Financial Item inputs are common to the accounting standards across countries and are easy to find. Financial ratios are simple and robust

03
Designed to deliver sizable predictive power across countries/regions

04
EDF measurements at 1-year horizon are calibrated to 4%. Given the heterogeneity across countries, Model outputs will be customizable to reflect different PD levels
RiskCalc: Identifying the Relevant Ratios to Estimate Default

We first identify broad categories of ratios relevant to default. We evaluate as many ratios per risk factor as possible.

Within each category, we then choose a limited no ratios which have:

- High predictive power
- Data availability
- Intuitive behavior

Each transformed ratio \([T(x_i)]\) is included in the regression, along with indicator variables for each industry \([I_j]\)

- \(F\) is the Final Calibration taking into account the Central Default Tendency

\[
FSO\ EDF = F\left(\Phi\left(\sum_{i=1}^{N} \beta_i T_i(x_i) + \sum_{j=1}^{K} \gamma_j I_j\right)\right)
\]
## RiskCalc Financial Inputs and Ratios and Weight

### Emerging Market Model Input List
- Cash and Marketable Securities
- Inventory
- Current Assets
- Total Assets
- Current Liabilities
- Total Liabilities
- Net Sales
- Net Sales Last Year
- Operating Profit
- Interest Expense
- Net Income
- Amortization & Depreciation
- Industry

<table>
<thead>
<tr>
<th>Section</th>
<th>Ratio</th>
<th>Weight</th>
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</thead>
<tbody>
<tr>
<td>Size</td>
<td>Sales</td>
<td>3.70%</td>
</tr>
<tr>
<td>Leverage</td>
<td>Total Liabilities / Total Assets</td>
<td>18.69%</td>
</tr>
<tr>
<td>Growth</td>
<td>Sales Growth</td>
<td>9.45%</td>
</tr>
<tr>
<td>Profitability</td>
<td>ROA</td>
<td>19.14%</td>
</tr>
<tr>
<td>Activity</td>
<td>Inventory / Sales</td>
<td>11.71%</td>
</tr>
<tr>
<td>Debt Coverage</td>
<td>EBITDA / Interest Expense</td>
<td>18.61%</td>
</tr>
<tr>
<td>Liquidity</td>
<td>Current Assets / Current Liabilities</td>
<td>18.71%</td>
</tr>
<tr>
<td></td>
<td>Cash &amp; Equivalents / Assets</td>
<td></td>
</tr>
</tbody>
</table>
Key principles when using external Data/Models

Institutions should leverage on external data to mitigate data shortage and augment internal data

Validated
Model performance to be tested on Institution Portfolio
Model re-estimated with a new representative portfolio if required

Representative
The data should be compared between external source and internal portfolio (Ex. Industries/Countries)
This assessment should also include an evaluation of default definition and the Credit Origination Policies

Incorporate Internal Profile
Even when using external input information the Institution is expected to combine it with the Internal Criteria.
Important to evaluate the alignment of the model versus internal expertise and adjust if needed

Ownership
Institutions are expected to have a good degree of understanding of the external information.
Avoidance of Black Box
Solutions should be auditable and replicable
Integration of models in the institution

The modelling techniques need to fit the institution, both from an IT and user perspective, and the following points should be taken into account:

- Balance between the statistical sophistication and the data available
- Models sophistication can grow through different generations
- Inclusion of the Key Stakeholders (Risk, Credit, Business) in the modelling process
- Transparency in the model calculation and final output that can be understood
- Importance of capturing the day to day credit/risk assessment
- Impact of the rating process, for example filling in the qualitative factors, in the model quality
Lessons learned from practice

First focus should be the risk drivers and not the data available

Be prepared to combine different methodologies - Use data where available and complement always with expert judgment to cover all risk drivers

Plan for the second model generation and start collecting data for the future

When using expert judgment collect opinions of a group of persons and not a single individual

Review outliers at the end and identify a clear reason for their existence (Model Limitations) possibly defining the override policies
Model Management
Process – Manage the models lifecycle & data

Robust data architecture and integrated platforms

Define structured models monitoring and change process leveraging on RW impact analysis

Link each model with the associated business process

Automated writing and storage of documentation

Collaborative Analytics Platform

Enrich your development and validation datasets

Define structured process flows and leverage on MA Pooled data models and methodologies

Ongoing validation frameworks leveraging on MA consortium solutions for immediate benchmarking
CAP - Process and User Roles Overview

Fully customizable to fit user’s own phases

**Modelers/Quants**
- **Modeler Copy of Project**
  - Create models with manager and team members
  - Write model documentation
  - Request for manager review
  - Adjust models per validator suggestion

**Manager/Approver**
- **Central Project for Development**
  - Creates project and forks to modelers
  - Review models
  - Review model documentation
  - Approve/reject
  - Create individual copy for validator

**Validators/Approvers**
- **Validator Copy of Project**
  - Test models
  - Review model documentation
  - Pass/fail
  - Create validated copy for manager

**Central Project for Deployment**
- Lock project for deployment
- Transfer ownership to deployer

**Production Copy of Project**
- Deploy model as API for QA
- Deploy model as API for Production

**Modeler Copy of Monitoring Project**
- Create monitoring process/app with manager and team member
- Request for manager review
- Support monitoring enhancement

**Central Project for Monitoring**
- Create project and forks to modelers
- Review monitoring process/app
- Approve/reject

**Production API**

**Deployer**

**Other processes and applications**
Moody’s Collaborative Analytics Platform & App Offering

The Challenge: Effectively Conducting Model Risk Management

» Banks and non-banking financial institutions model risk management often rely on multiple systems, separate Excel, SAS or R / Python codes and model documentation spread out across many different teams.

» Many of these processes are labor intensive and rely on knowledge of the specific individuals.

» Traceability often becomes a problem as systems for handling datasets and modeling decisions are often missing or spread across multiple divisions.

» New developments or changes to existing models require a long project execution timeline and considerable effort for implementation/testing.

The Solution: A workflow and mass scale approach to Model Risk Management

» Ensures traceability by allowing users to store data and modeling decisions from data quality to chosen factors and final model.

» Combines internal and external data in a seamless way.

» Allows the users to see results in real time with the option of writing automatic reports in your chosen format (pdf, word, pptx etc).

» By using our cloud based computing power, you can run extensive modelling jobs with increased efficiency.

» Final models can be released via API’s and placed into the CAP model inventory becoming “production ready.”
Model Validation
Model Validation App

Client Portfolio Data, Rating to PD Mapping
- Historical Portfolio Data
- Challenger Model PD (or RiskCalc Input for client portfolio)
- Rating to PD Mapping Master scale
- Model Score Structure (if available)

Model Validation
- Data Quality and Preparation
  - Single Factor Analysis
- Model Level analysis (back-testing)
- Benchmarking – Option to run RiskCalc
  - Automated Report Writing

Outputs
- Intermediate Data – After Data Cleaning
  - Data Cleaning Rules
  - Validation Decisions
- Automated Report (pptx, word, pdf)
Model Validation App: Program Features

(1) Data Agnostic: Client portfolio data and RiskCalc input data is accepted but no hard structure necessary

(2) Data quality and preparations: Users can make data preparations and store decisions for later use

(3) Allows user to drill into results through interactive graphs and a multitude of validation analysis options

(4) Intermediate output exports to Excel, final output exports to PPT and Word and pdf incorporating real-time user commentary
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Moody’s CreditLens
Next Generation Credit Assessment & Origination Architecture
Agenda

1. Why is a Credit Risk Rating Solution required?
2. CAP™ for Model Lifecycle Management
3. CreditLens™ as a Credit Risk Rating solution
4. CreditLens Demonstration
Why is a Credit Risk Rating Solution required?
Challenges: PD modelling approach

The approach to PD modelling depends on the amount of existing data in the organization's respective portfolio:

- **No data availability**
  - Off-the-shelf
  - Localization approach

- **Some data availability**
  - Verification Approach
  - Shadow Rating Approach

- **Large historical dataset available**
  - Statistical Approach

**Models (RiskCalc) + Data (CRD and DRD)**

**Data Availability**: The two key elements are number of obligors and number of defaults in the past (for example over the last 5 years) per relevant portfolio.

**IRB Accelerator**: The use of an off the shelf model as for Example RiskCalc as the starting point can reduce the Development Timelines and increase the statistical robustness of the final model.
Challenges: Banking

- Delayed Audits
- Culture of regular ratings.
- Scanty data for SMEs
  - No audits
  - Poor bookkeeping
  - Basic data missing - Turnover
- Financial performance and Credit ratings are lagging indicators of risk
- Expertise – Smaller financial institutions
Why is a Credit Risk Rating solution required?

Benefit from the investment made on developing rating models

**LEVERAGE INVESTMENT**
Leverage the investment to develop rating models
Reduced the cost of operations
Outputs from the model helping make better informed credit decisions

**OPERATIONAL EFFICIENCY**
Reduce the need for manual processes
Central system
All the data in one place
Reduce cost for rating customers

**RISK & REGULATOR**
Active Risk Monitoring
Consistent, Quality Data
Accurate Risk Assessment
Robust Risk Control
Impacts the whole bank - The Virtuous Cycle

- Basel III regulatory capital
- Credit Assessment and Origination
- IFRS 9
- ALM/FTP
- RAROC Calculator
- Simulations, scenarios, stress testing
- Ex-post RAROC
- Limit Management
- Capital allocation process
- Capital
- Limits
2 CAP for Model Lifecycle Management
Collaborative Analytics Platform (CAP)
A centralized model development, validation and deployment platform for orchestration of model execution and easy deployment to Moody’s application in a well governed and efficient manner

SUPPORT FOR
- Model development in R, SAS, Python and other open source languages
- Model development workflow for individual and systems of models
- Model inventory dashboard and tracking
- Full model documentation repository
- Central model monitoring application
- API to deploy models via restful calls
3 CreditLens for Credit Risk Solution
Relevance for this Region: it's all there!
Let Bankers Do More Banking with CreditLens

Customer Management
- Entity demographic, Hierarchy
- Financial Spreading
  - Multi-templates
  - AI Spreading Automation
  - Financial Data (BvD)

Credit Assessment
- Credit Rating (PD)
- Multi-models
- Internal Rating Model engine
- CreditEdge
- RiskCalc
- Third-party calculation engines

Deal Structuring
- Facility Structuring
- Collateral Structuring
- Loss-Default Analysis (LGD)
- Risk Return Analysis (RAROC)
- Specialized Lending Analysis (CRE) + CMM
- Covenants

Decisioning & Approvals
- Obligor Exposure Aggregation (in-memory)
- Approval level computation
- Electronic Approvals by
  - Business Review
  - Group Credit
  - Credit Committee Secretariat

Credit Memo & Reports
- Credit Memo
- File Attachments
- Reports
- Notification
- Portfolio Report with Business Insights (BI)

Post Approval & Monitoring
- Letter of Offer Generation
- SLA Tracking and Monitoring
- Line Implementation
- Post-Disposition
- Covenants Monitoring
- Sentiment Score - Early Warning leveraging AI

Customer Management

Credit Lens
- Advanced Designer (CLAD)
- Rest APIs
- AI & Machine Learning
- Cloud & SaaS
- Report Designer
- Model Authoring Tools
- Multi-Language
Engineered for Modularity

Modular for use in whole or part across the lifecycle of the loan
Analytics
Powerful financial analysis and risk grading developed over 30 years

» Probability of Default and Loss Given Default measures
» Industry standard and custom ratio analysis
» Multiple accounting templates available to support regional and industry specific accounting standards
» Integration with our 30 industry and regional specific market leading RiskCalc models, which leverage the largest global database of private company financial information
» Integration with internal, regulator approved models, or statistical platforms such as ‘R’
Deeper insight and control of the entire relationship

Provides a consistent and complete view for risk assessment

**Entity Management**

» Dedicated entity management module provides core building block

» Provides an overview of how the entity is performing

» Construct relationship structures pivotal to accurate risk assessment

» Tune and validate data capture in accordance with entity type – improving data strength and quality

» Control and distribute risk grades within a relationship
Deeper, efficient spreading designed for speed

Financial Analysis

» Capture financial information in multiple formats by industry or accounting standards

» Automated spreading using OCR and machine learning technology

» Spreading grid HTML based with excel feel

» Ability to create projections using the historical financial statements

» Easy to use (copy/paste, undo/redo, search, etc.)

» Combine accounts from multiple entities

» Hard-lock statements

» Show accounts with values only

» Statement level currency

» Automated duplicate checking

» Standard out of the box reports – Financial, Peer Comparison, Consultant, Projection
In-depth assessment of borrower health

Risk Grading

» Out of the box rating models (SME’s, Middle Market, Corporates, etc.)
» Hierarchical grade distribution
» Configurable automated model selection
» Support for multiple scenario’s including what-if for stress assessment
» Extended override classifications
» Optional business process management control
» Model as Service - ‘R’ Integration
CreditLens Demonstration
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