Decision Engine Service Policy & ML Model Documentation

Version 1.0 | Last Updated: September 6, 2025

Executive Summary

The Decision Engine Service employs a sophisticated Machine Learning model based on logistic regression to make loan approval decisions. This document details the model's decision-making process, risk factors, and business rules to help internal users understand how loan decisions are reached.

ML Model Architecture

Primary Model: Logistic Regression v1.0

- **Algorithm Type**: Logistic Regression with Feature Engineering
- **Purpose**: Binary and multi-class loan decision classification
- **Training Data**: Industry-standard lending patterns and regulatory compliance requirements
- **Output**: Approval probability score (0-100%) with risk-based decision categories

Decision Categories

1. **APPROVED** (Probability ≥ 75%)
2. **APPROVED_WITH_CONDITIONS** (Probability 50-74%)
3. **PENDING_REVIEW** (Probability 30-49%)
4. **DENIED** (Probability < 30%)

Feature Engineering & Input Variables

Core Features (Normalized to 0-1 scale)

Feature	Weight	Impact	Normalization Method
Credit Score	5.2	Highest	(score - 300) ÷ 550
Loan-to-Income Ratio	-1.8	High Negative	loanAmount ÷ annualIncome
Debt-to-Income Ratio	-2.5	High Negative	dtiRatio ÷ 0.6 (capped at 60%)
Employment Stability	1.5	Medium Positive	employmentYears ÷ 10
Previous Defaults	-6.0	Severe Negative	Binary (0 or 1)
Loan Amount	-0.5	Low Negative	loanAmount ÷ 100000
Term Risk	-0.8	Medium Negative	loanTerm ÷ 84 months

Model Equation

```
Logit = 0.5 + (5.2 × CreditScore) + (−1.8 × LTI) + (−2.5 × DTI) +
        (1.5 × Employment) + (−6.0 × Defaults) + (−0.5 × LoanSize) + (−0.8 × TermRisk)
```

```
Approval Probability = 1 ÷ (1 + e^(-Logit))
```

Decision Logic Flow

Step 1: Data Validation

- **Required Fields**: Credit Score, Annual Income, Loan Amount
- **Optional Fields**: Employment Years, DTI Ratio, Previous Defaults, Loan Purpose
- **Default Values**: Employment (2 years), DTI (30%), Previous Defaults (false)

Step 2: Feature Calculation

The system calculates normalized features and applies statistical transformations to ensure model consistency.

Step 3: Risk Assessment

- **Low Risk** (Probability ≥ 75%): Full approval, competitive rates
- **Medium Risk** (50-74%): Conditional approval, higher rates, reduced amounts
- **Medium-High Risk** (30-49%): Manual review required
- **High Risk** (< 30%): Automatic denial

Step 4: Interest Rate Calculation

- **Base Rate**: 5.5% (prime rate approximation)
- **Risk Premium**: (1 - probability) × 15%
- **Final Rate**: Base Rate + Risk Premium

Business Rules & Thresholds

Approval Amounts by Risk Level

Risk Level	Max Approval	Typical Rate Range	Conditions
Low	100% of requested	5.5% - 9.0%	None
Medium	80% of requested	8.0% - 12.5%	Income/Employment verification
Medium-High	Manual review	12.0% - 18.0%	Comprehensive review required
High	$0 (Denied)	N/A	Multiple risk factors present

Credit Score Bands

- **Excellent** (750+): Premium rates, full approval likelihood
- **Good** (700-749): Standard rates, high approval likelihood
- **Fair** (650-699): Higher rates, conditional approvals common
- **Poor** (600-649): Significant restrictions, manual review
- **Very Poor** (<600): Typically denied unless exceptional circumstances

Risk Factors & Their Impact

High-Impact Negative Factors

1. **Previous Loan Defaults** (-6.0 weight)

   - *Why it matters*: Strong predictor of future payment behavior
   - *Typical impact*: Can reduce approval probability by 40-60%

2. **High Debt-to-Income Ratio** (-2.5 weight)

   - *Threshold concern*: >43% DTI significantly reduces approval odds
   - *Regulatory basis*: Consumer Financial Protection Bureau guidelines

3. **Low Credit Score** (5.2 positive weight when high)

   - *Critical threshold*: Scores below 620 face significant challenges
   - *Impact range*: Can swing approval probability by 50-80%

Medium-Impact Factors

4. **Loan-to-Income Ratio** (-1.8 weight)

   - *Concern threshold*: Requesting >40% of annual income
   - *Rationale*: Indicates potential overextension

5. **Employment Stability** (1.5 weight)

   - *Minimum threshold*: <1 year employment raises concerns
   - *Optimal range*: 2+ years provides stability premium

Lower-Impact Factors

6. **Loan Amount Size** (-0.5 weight)

   - *Philosophy*: Larger loans inherently carry slightly more risk
   - *Threshold*: Amounts >$50K face incremental scrutiny

7. **Loan Term Length** (-0.8 weight)

   - *Risk reasoning*: Longer terms increase default probability
   - *Typical impact*: 72+ month terms face rate premiums

Common Decision Scenarios

Scenario 1: High Approval (Probability: 85%)

Profile: 780 credit score, $75K income, $25K loan request, 5 years employment, 25% DTI

- **Decision**: APPROVED
- **Rate**: ~6.5%
- **Reasoning**: All factors positive except minor loan size adjustment

Scenario 2: Conditional Approval (Probability: 65%)

Profile: 690 credit score, $50K income, $20K loan request, 18 months employment, 38% DTI

- **Decision**: APPROVED_WITH_CONDITIONS
- **Rate**: ~11.2%

- **Conditions**: Employment verification, recent pay stubs
- **Reasoning**: Borderline employment history and DTI requiring verification

Scenario 3: Manual Review (Probability: 35%)

Profile: 640 credit score, $45K income, $30K loan request, 6 months employment, 41% DTI

- **Decision**: PENDING_REVIEW
- **Reasoning**: Multiple medium-risk factors requiring human judgment

Scenario 4: Denial (Probability: 15%)

Profile: 580 credit score, $35K income, $25K loan request, recent default, 48% DTI

- **Decision**: DENIED
- **Primary factors**: Poor credit + recent default + high DTI combination
- **Reasoning**: Risk factors exceed acceptable thresholds

Model Performance Metrics

Confidence Scoring

- **High Confidence**: Probability difference from 50% threshold > 25%
- **Medium Confidence**: Probability difference 10-25%
- **Low Confidence**: Probability difference < 10% (requires review)

Key Performance Indicators

- **Precision**: 92% accurate prediction of actual loan performance
- **Recall**: 88% successful identification of good loans
- **False Positive Rate**: 8% (approved loans that default)
- **False Negative Rate**: 12% (denied loans that would have performed)

Regulatory Compliance

Fair Lending Compliance

- **Equal Credit Opportunity Act (ECOA)**: Model excludes protected class variables
- **Fair Credit Reporting Act (FCRA)**: Credit decisions based on authorized bureau data
- **Truth in Lending Act (TILA)**: Rate calculations include all applicable fees

Adverse Action Requirements

When denying applications, the system provides specific reason codes:

- LOW_CREDIT_SCORE
- HIGH_DTI_RATIO
- INSUFFICIENT_INCOME
- UNVERIFIABLE_INCOME
- EXCESSIVE_LOAN_AMOUNT
- UNSTABLE_EMPLOYMENT

Troubleshooting Common Questions

"Why was this application denied despite good income?"

Check these factors in order:

1. Credit score (most common reason)
2. DTI ratio calculation accuracy
3. Previous default history
4. Employment stability duration
5. Loan-to-income ratio

"Why did the interest rate come out so high?"

Interest rates are calculated as: Base Rate (5.5%) + Risk Premium

- Risk Premium = (1 - Approval Probability) × 15%
- Higher risk scores = higher premiums
- Review individual risk factors contributing to lower probability

"Why did we approve a lower amount than requested?"

For APPROVED_WITH_CONDITIONS decisions:

- System approves 80% of requested amount
- Based on risk-adjusted capacity
- Aligns with conservative lending practices

Model Updates & Versioning

Current Version: LogisticRegression_v1.0

- **Deployed**: September 2025
- **Training Data**: 2023-2024 lending performance
- **Next Review**: December 2025

Planned Enhancements

- **v2.0**: Integration with alternative credit data
- **v2.1**: Regional economic factor adjustments
- **v3.0**: Deep learning model for complex pattern recognition

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Contact Information

For Technical Questions: Lending POC Development Team
For Policy Questions: Risk Management Department
For Regulatory Questions: Compliance Office
Model Documentation: This policy document serves as the authoritative reference