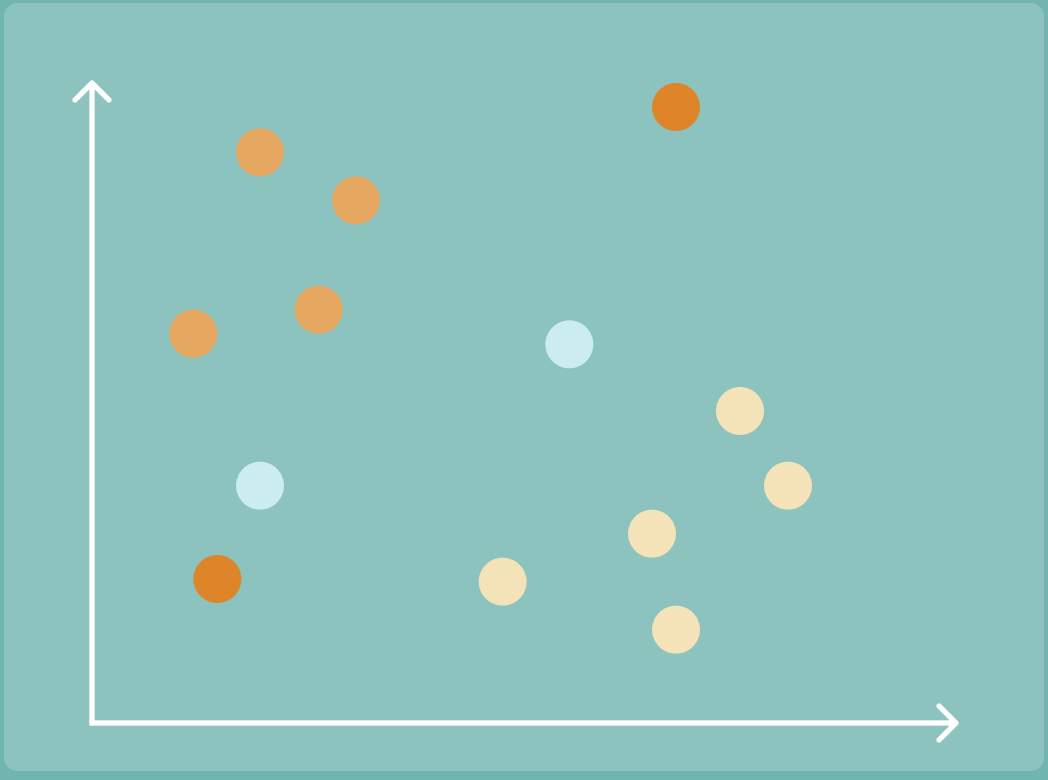
Customer Segmentation for Auto Loan Prepayment Optimization

Analytical Framework for Measuring Early Payoff Behavior

Ian Moore | 9/27/2025

github.com/imoore99/TWO_STAGE_CLUSTER

ianmooreanalytics.com



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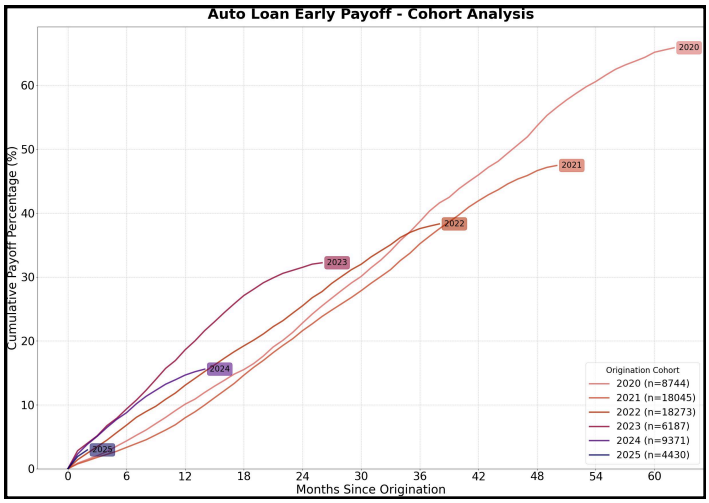
Business Context

- **Issue:** The loan portfolio is experiencing declining balances, especially in the auto segments, despite consistent application volumes. The concern is early payoff patterns may be affecting portfolio yield and profitability.
- **Request:** Management has requested an analysis of prepayment behaviors. Their primary goal is to identify key drivers behind this trend as well as key customer segments to target. The analysis should provide recommendations for portfolio optimization and customer lifecycle management.
- **Approach:** The analysis will proceed in four parts to address management's request. First, cohort analysis will quantify prepayment patterns across different origination periods and product segments to establish baseline cohort behaviors. Second, advanced clustering methodology will segment customers based on prepayment characteristics to identify distinct behavioral groups. Third, detailed customer profiles will translate analytical findings into actionable business intelligence for targeted retention strategies. Finally, a framework for immediate action and continued optimization.
- **Data:** 26,667 records. 8 features.

Part 1: Elevated Early Payoff Behavior

The data was split into annual cohorts to perform a baseline review of payoff speeds. This cohort analysis does reveal a shift in early payoff behavior that began in 2022. The 2023 and 2024 vintage cohorts do show accelerated prepayment patterns compared to the 2020-2022 baseline period, with early payoff rates nearly doubling at some comparable loan vintages.



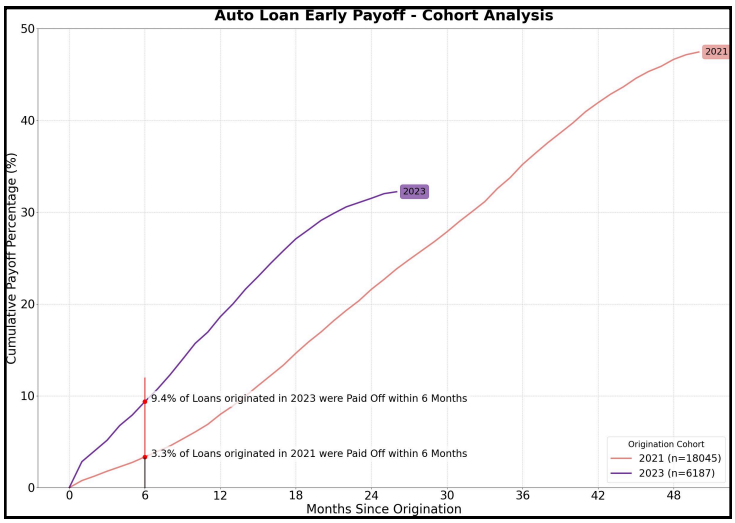
Payoff Rate Baseline (2020-2022): Cohorts exhibit relatively consistent early payoff trajectories, reaching approximately 35% at 36 months

Payoff Rate Increase (2023-2024): Both vintages show markedly steeper prepayment curves, with 2023 loans reaching over 30% early payoffs by just 24 months compared to 20-25% for earlier cohorts.

Current Rate Cycle (2025): Current cohort is slightly lower than 2023 and 2024, but is still higher than the baseline. A comprehensive evaluation will provide better results for comparison at year-end.

Dramatic Early Payoff Acceleration: Nearly 3x Increase During Rate Hiking Cycle

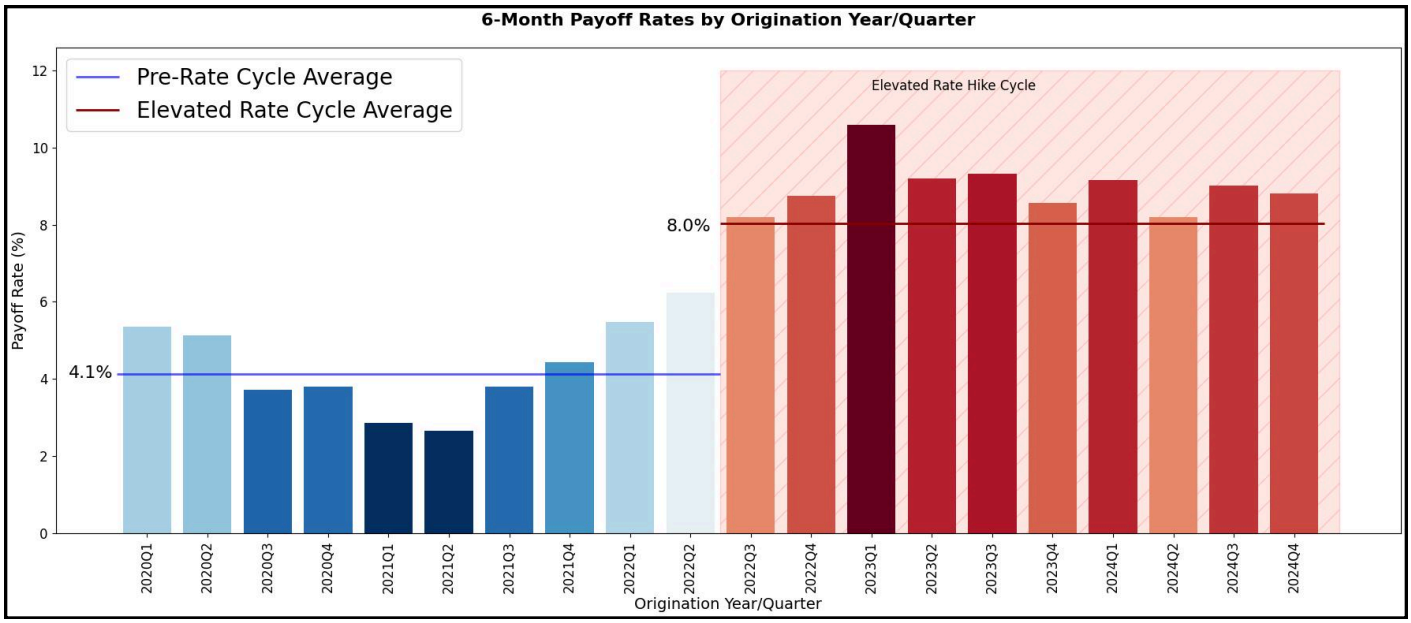
Comparative analysis between 2021 and 2023 vintage cohorts shows the profound impact the rate hiking cycle had on borrower behavior. The intent was to measure the six-month performance differential as an exploratory sample and found 2023 originations had 9.4% cumulative payoffs compared to just 3.3% for 2021 originations. **This represents a 185% increase in prepayment velocity, or nearly three times the 2021 rate.**



Clear Regime Change: Q3 2022 Marks Onset of Sustained Early Prepayment Acceleration

Further deconstructing the 6-month payoff rates by origination year and quarter, there is clear evidence of a structural shift in borrower behavior that coincides with the elevated rate environment. **The average payoff rate pre-rate cycle was 4.1% - from Q3 2022 onward the average payoff rate increased to 8.0%.**

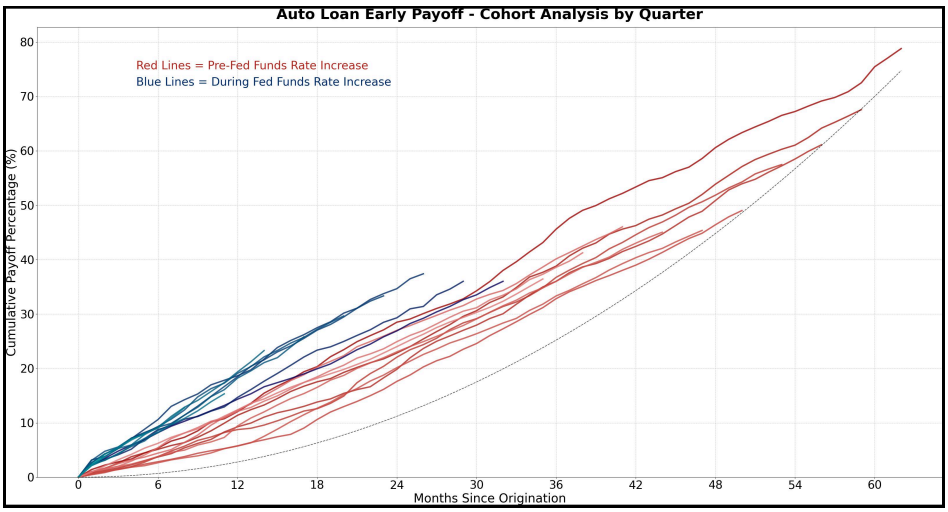
The Q3 2022 breakthrough to 8.2% marks the definitive regime change in early prepayment behavior, with 6-month payoff rates never returning to pre-cycle levels. The subsequent peak of 10.7% in Q1 2023 represents the inflection point of early prepayment velocity. Even after this peak, there is continued borrower urgency to quickly optimize or exit financing arrangements during the heightened rate environment.



Three distinct early prepayment regimes emerge during this period. First, a **Pre-Rate Stability Cycle** where early payoff rates remain consistently low and stable between 3-5%. Second, a **Transition Period** in Q2 and Q3 2023 show a sharp inflection beginning at 6.4% (Q2) to 8.2% (Q3), representing the first clear signal of changing borrower dynamics. Third, **Elevated Rate Environment** is where six-month rates stabilize at a new baseline over 8% representing **over a 200% increase** from pre-cycle norms.

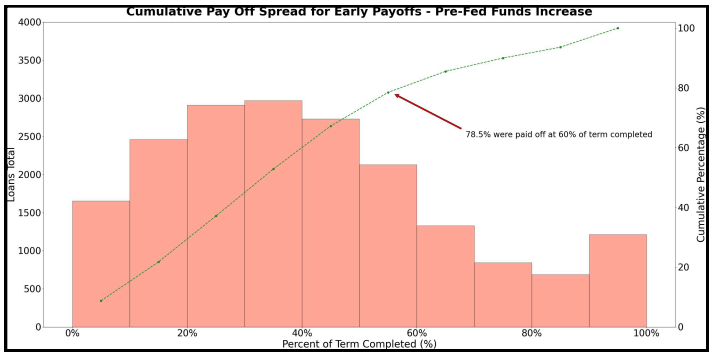
Definitive Visual Evidence of Monetary Policy Impact on Prepayment Behavior

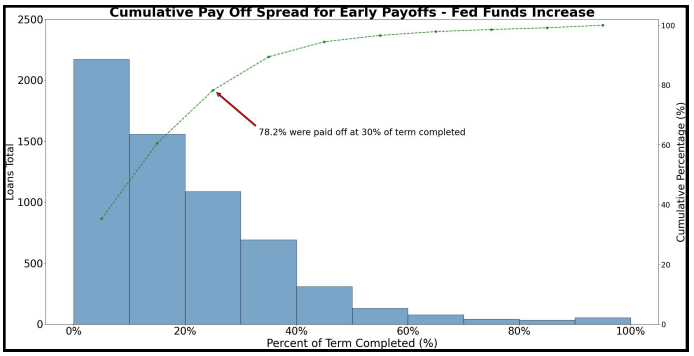
The cohort analysis reveals a clear separation between **pre-rate increase (red)** and **rate increase period (blue)** cohorts. The complete separation between red and blue line clusters eliminates any ambiguity about causation - this is clearly a monetary policy-driven regime change rather than gradual portfolio evolution. The blue cohorts' steeper trajectories and higher early cumulative payoff rates clearly demonstrate that borrowers originated during the rate hiking cycle exhibit fundamentally different repayment urgency compared to low-rate period originations.



Cumulative Pay Off Spread Analysis: Pre vs During Fed Funds Rate Increase

A comparative analysis was performed of cumulative payoff speeds before and after the monetary policy changes. On the prior page, we saw prepayment speeds increasing in the elevated rate environment. The cumulative spread analysis shows the life of loans has compressed to a significantly shorter period.



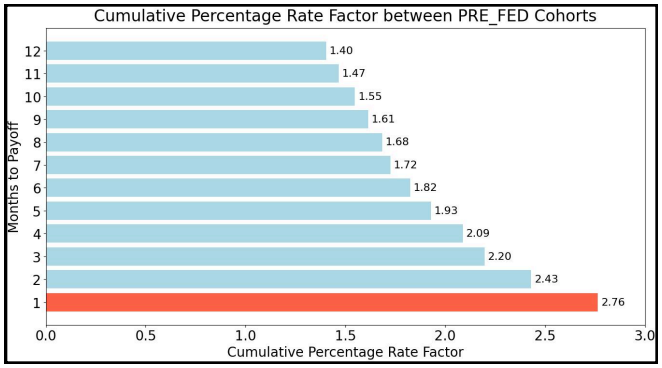


Prior to the Federal Reserve's rate hiking cycle, auto loan payoffs followed a traditional distribution pattern concentrated in the middle and later stages of loan terms. Analysis shows 78.5% of early payoffs occurred after borrowers completed 60% of their loan term (approximately 40 months for the average 67-month loan). This pattern reflects stable refinancing behavior where borrowers typically waited until mid-term to seek better rates or payoff opportunities.

During the **rate hiking cycle,** auto loan payoffs were fundamental altered as **78.2% of early payoffs occurred by just 30% of term completion**, or roughly 20 months (also averaging 67-month loan) – with **38% occurring in the first 6 months**. This represents a dramatic compression of payoff timing to the earliest stages of loan lifecycle.

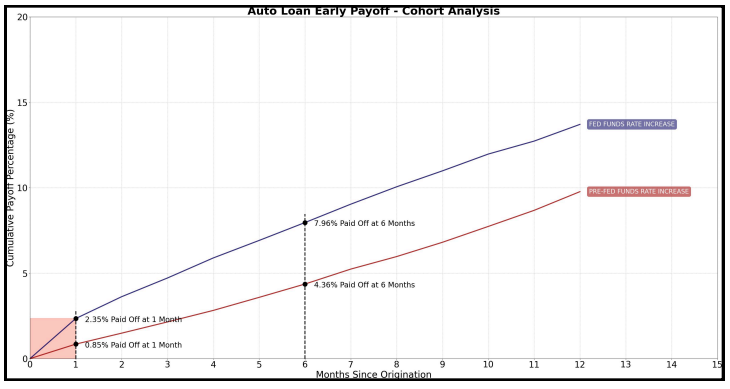
This shift, combined with the 3x increase in overall payoff velocity, creates continued portfolio challenges: loans not only pay off more frequently but do so before significant interest accrual occurs, severely impacting portfolio yield and profitability. The concentration of prepayments in early loan stages suggests borrowers are accessing alternative financing or cash resources much sooner than historical patterns.

Cumulative Percentage Rate Factor Between Pre-Fed and Fed Rate Increase Cohorts



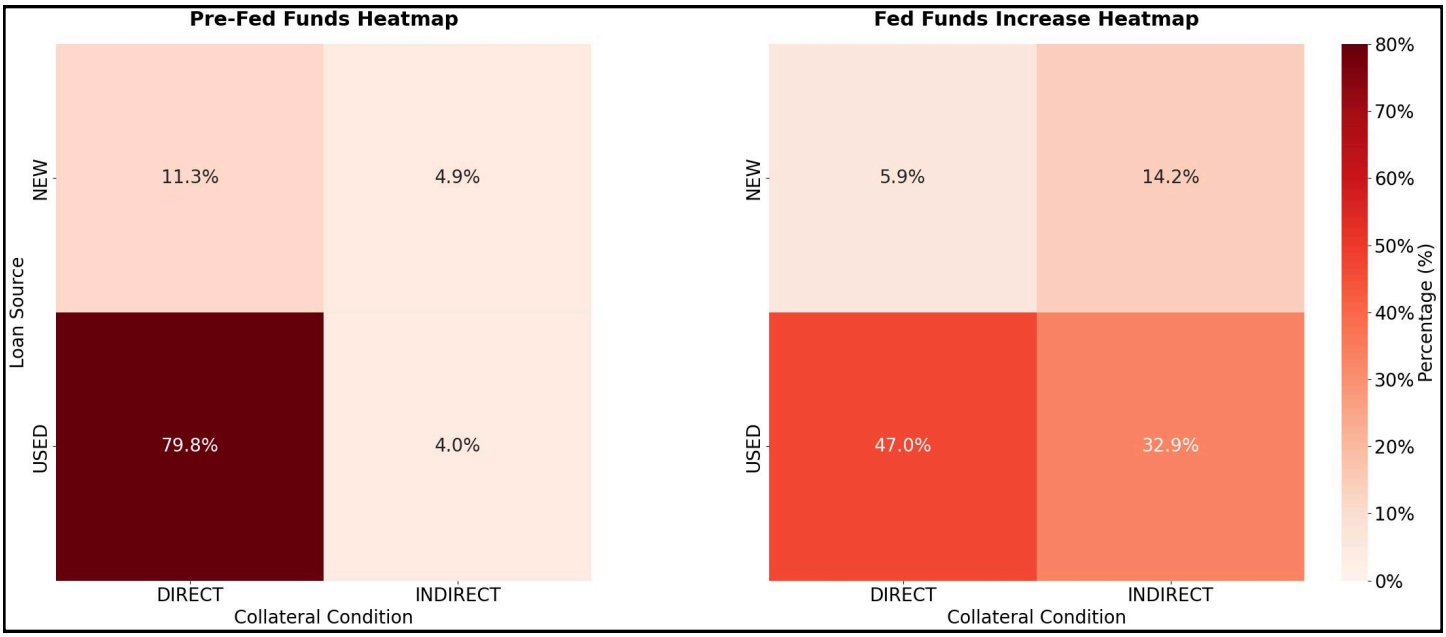
Given the early payoff speeds have significantly compressed into a shorter period of the loan's lifecycle, it is important to determine the highest priority target for portfolio management intervention. One-month payoffs have an acceleration of 2.76x representing the most severe behavioral shift in the entire prepayment timeline. Month 1 exceeds all other periods, making it the single largest driver of portfolio cash flow disruption and loan lifecycle compression.

The trajectory at which early payoffs have increased in the first month demonstrates both the magnitude and persistence of behavioral changes across environments. **The baseline prior to the rate hiking cycle was 0.85%, increasing to 2.35%.** For comparison, the gap widens to 4.36% vs 7.96%, however the rate factor is lower at 1.82x. Therefore, **one-month payoffs represent the worst-case scenario for operational efficiency - full origination, underwriting, and booking costs incurred with no interest income capture to offset expenses.**



Heatmap Analysis of One-Month Early Payoffs Indicates Portfolio Shift

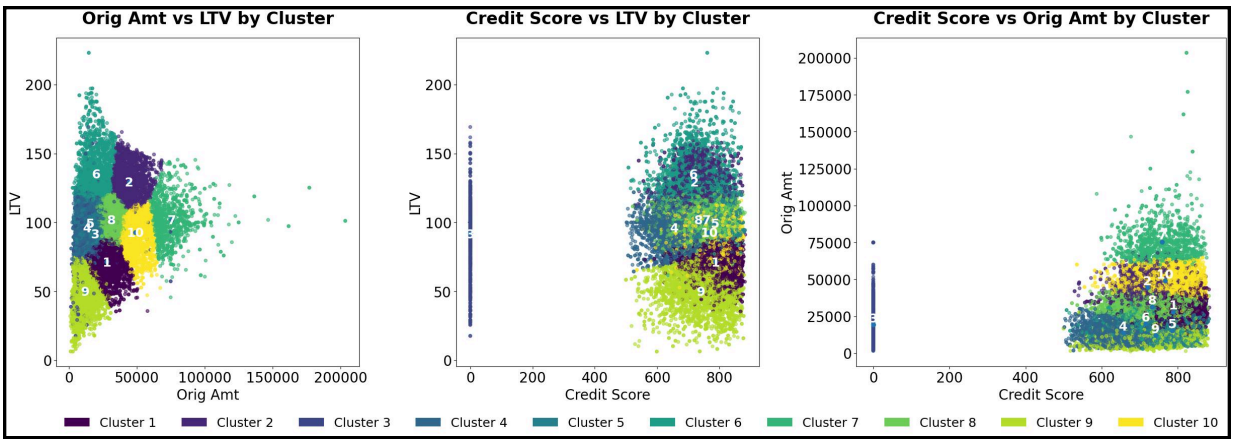
Targeting the one-month early payoffs indicates, the composition of early payoffs has shifted dramatically. Prior to the rate hiking cycle, 79.8% of one-month early payoffs was used direct auto loans. However, used direct loans declined from 79.8% to 47.0% representing a 41% reduction. New Indirect loans increased from 4.9% to 14.2%. **Most significantly used indirect loans rose from 4.0% to 32.9% of payoffs, representing an 8x increase** – this is likely a major contributor to the early payoff volume and will be explored in the cluster analysis.



During the elevated rate cycle, early payoff velocity increased significantly. This resulted in a compression of the loan lifecycle which would result in a reduction in profitability and cash flow. **One-month payoffs experience the largest increase and represent a significant operational issue as the cost to acquire the loan has been incurred with no interest income to be captured in the future.** In addition, we can see that different product combinations (Direct/Indirect, New/Used) respond differently to rate environments. In Part 2, having identified one-month payoffs as the critical intervention point, we'll segment these early payoff customers using a clustering methodology to identify distinct behavioral groups and find high-impact targets for intervention.

Part 2: Cluster Analysis Framework

The cluster analysis will incorporate both traditional credit risk variables (credit scores, loan amounts, LTV) and the product mix factors identified in the heatmap analysis (loan source, collateral condition) to create comprehensive risk segments that explain one-month prepayment behavior across different market conditions.



The three-dimensional scatter plot analysis confirms that the K-means algorithm successfully identified ten distinct customer segments with meaningful separation across loan amount, LTV, and credit score dimensions. The visual clustering validates the statistical segmentation and provides insight into the risk and business characteristics driving one-month payoff behavior.

Some key observations:

- **Cluster 3:** appears to concentrate at a zero credit score. These are auto-approved loans that appear to have moderate LTV and loan amounts.
- **Cluster 7:** has higher LTV, higher original amounts and higher credit scores. This is potentially a large loan prime borrower.
- **Clusters 1, 5, 9:** form distinct low-LTV segments across different credit and loan amount ranges, suggesting conservative financing customers with lower prepayment risk
- **Clusters 2, 6:** occupy the high-LTV space, indicating aggressive financing that may drive different behavioral patterns
- **Clusters 4:** concentrates in the lower loan amount/moderate credit space, representing the traditional small-balance lending segment

K-means Cluster Analysis: Complete Profile Summary

A profile summary was compiled for each cluster, analyzing key loan characteristics including LTV, original loan amount, and credit score at origination. Early payoff rates were calculated to identify clusters exceeding critical risk thresholds. Using the baseline rate of 2.35%, clusters were categorized as high risk (>3.5%, representing 1.5x baseline), medium risk (>3%, representing 1.3x baseline), or standard risk. This analysis identified Cluster 3 with a 3.56% early payoff rate as the primary high-risk segment, and Cluster 7 with a 3.34% rate as a medium-risk segment.

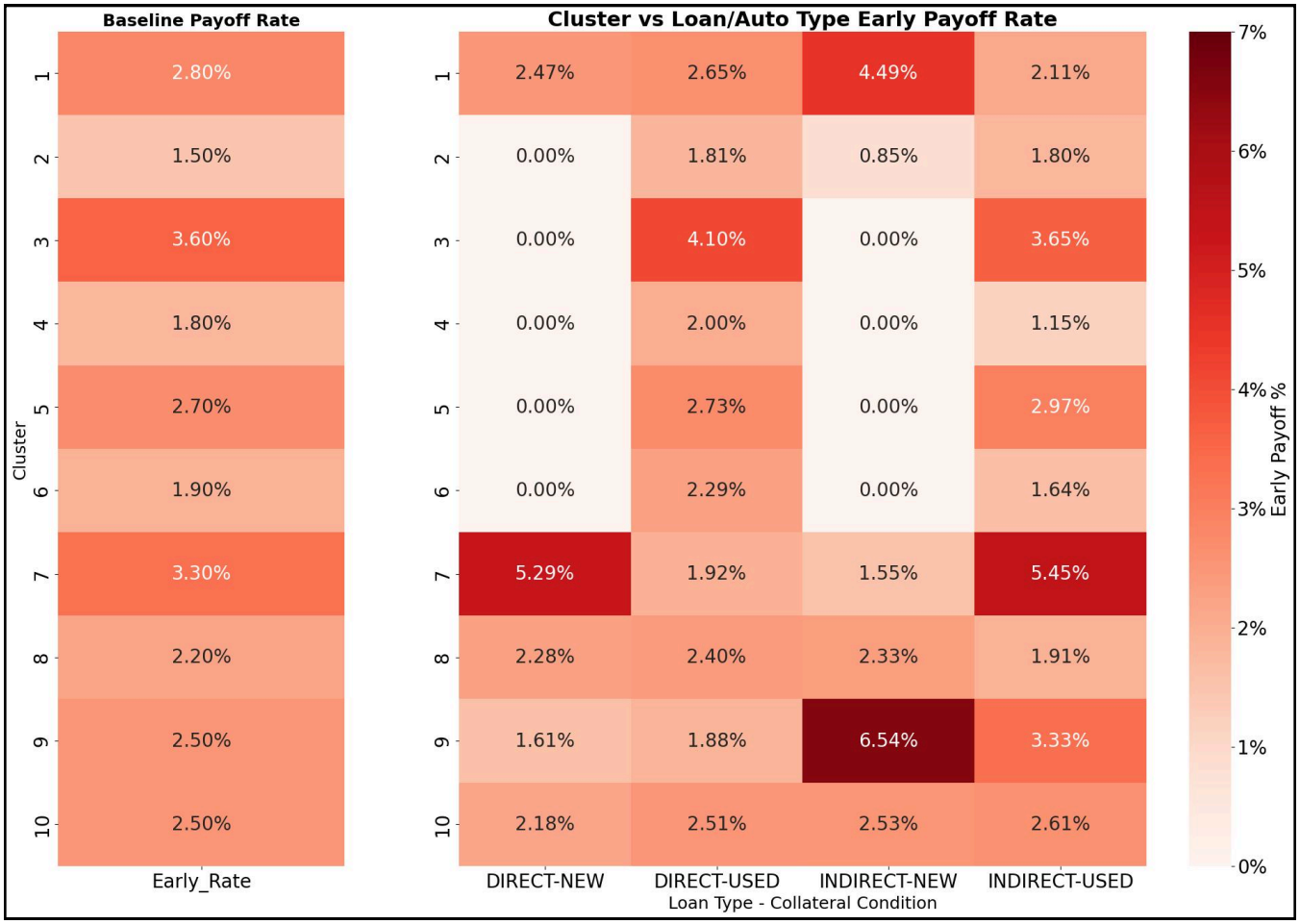
K-means Cluster Analysis: Complete Profile Summary

	ltv_orig	credit_score_orig	amount_orig	Count	Early_Payoffs	Early_Rate (%)	Pct_DIRECT (%)	Pct_INDIRECT (%)	Pct_NEW (%)	Pct_USED (%)
Cluster 1	71.46	787.0	27945.18	3358.0	94.0	2.8	39.85	60.15	27.81	72.19
Cluster 2	129.51	719.0	44471.92	1976.0	30.0	1.52	14.12	85.88	26.82	73.18
Cluster 3	91.97	0.0	19222.4	984.0	35.0	**3.56**	84.55	15.45	11.69	88.31
Cluster 4	96.28	656.0	13813.1	3787.0	70.0	1.85	85.69	14.31	1.77	98.23
Cluster 5	99.59	784.0	15415.92	2778.0	74.0	2.66	71.89	28.11	4.86	95.14
Cluster 6	135.45	715.0	20004.29	2313.0	43.0	1.86	38.22	61.78	1.56	98.44
Cluster 7	102.1	758.0	75472.2	1108.0	37.0	3.34	29.42	70.58	56.14	43.86
Cluster 8	102.01	732.0	31376.17	4493.0	98.0	2.18	47.76	52.24	22.19	77.81
Cluster 9	50.29	741.0	12112.09	3230.0	80.0	2.48	72.91	27.09	10.46	89.54
Cluster 10	92.87	766.0	48979.69	2640.0	66.0	2.5	32.23	67.77	47.08	52.92

Color Coding: • Red highlight: Early payoff rate > 4% (high risk) • Orange highlight: Early payoff rate > 3% (medium risk) • Pink cells: High LTV (>90%) • Light green cells: Low LTV (<70%)

High-Risk Cluster observations show that cluster 3 (3.56% early payoff rate) indicates this to be a thin file borrower (zero credit scores) with 84.5% direct and 88.3% used. These are likely auto-approved borrowers seeking an easy approval at origination but also quick refinance opportunists. Cluster 7 (3.34% early payoff rate) are borrowers with good credit (average 758) high loan amounts (average $75,472) and LTV's over 100%. These are likely high-income, sophisticated borrowers managing large debt positions. However, Cluster 9 (2.48% early payoff rate) may represent low risk protective position as these borrower show the lowest LTV (50.29%) with good credit and direct origination, representing conservative financing customers with stable payment behavior.

Product Mix Reveals Hidden Risk Concentrations Within Cluster Segments



Part 1 established a baseline one-month payoff rate of 2.35%. Stage one clustering identified clusters 3 and 7 as elevated risk segments at 1.5x and 1.3x the baseline payoff rate. Stage two applies product dimensions (loan source and collateral condition) to isolate the highest-risk subsegments within these clusters.

This two-stage segmentation reveals 15 product-cluster combinations exceeding baseline, with five critical segments showing extreme early payoff rates between 1.7x and 2.8x the baseline:

- **Cluster 1:** Indirect New (4.49% - 1.9x baseline)
- **Cluster 3:** Direct Used (4.10% - 1.7x baseline)
- **Cluster 7:** Direct New (5.29% - 2.3x baseline)
- **Cluster 7:** Indirect Used (5.45% - 2.3x baseline)
- **Cluster 9:** Indirect New (6.54% - 2.8x baseline)

These five segments represent the highest-priority targets for retention intervention. Part 3 will develop detailed customer profiles and targeted recommendations for each segment.

Part 3: Target Customer Profiles for Intervention

Cluster 1: Indirect New (4.49% - 1.9x Baseline)

SUPER-PRIME MODERATE-LEVERAGE NEW CAR FLIGHT RISK

The Profile: Solid credit customers (787 average score) making conservative new vehicle purchases with strong equity (71% LTV average, $28K loans). These are financially sophisticated buyers with excellent credit who choose dealer financing despite having access to the most competitive rates in the market.

The Hidden Risk: Every early payoff had a credit score of 770 or greater. When this core risk group is isolated, the early payoff rate increases to 6.05% - 280% above the baseline. This segment represents the "too good to keep" problem – our best credit risks are our worst retention risks when they come through indirect channels on new vehicles.

The Problem: They either need to be priced in or priced out of the portfolio. Pricing in mean accepting the underwriting costs and pricing below market for longer-term retention. Pricing out means an additional 75+ bps for new indirect loans with 770+ credit scores and moderate LTV's.

Recommendations:

- **Price Out of Portfolio:** Raise rates for this segment 75+ bps and focus on reducing early payoffs by limiting segments with high payoff rates
- **Dealer Rate Adjustment:** Reduce dealer reserve on super-prime new car loans as initial barrier
- **Relationship Pricing for Retention:** Offer relationship and tenure-based pricing. Notify borrowers of possible interest rate reductions at 6 or 12 months to curb quick refinancing

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Cluster 3: Direct Used (4.10% - 1.7x Baseline)

AUTOMATED SCORING USED CAR REFINANCERS

The Profile: Automated underwriting customers financing older, lower-value vehicles with minimal equity. These are borrowers with very little money down (92% LTV average) on used cars averaging $17K. These are direct borrowers using the opportunity for a quick refinance.

The Hidden Risk: All early payoffs had a balance of $32,000 or less. When this core risk group is isolated, the early payoffs increase to 4.8%.

The Problem: The automated scoring system approves loans that are being leveraged as stepping stones to better financing. Members likely use high-LTV used vehicle financing to consolidate debt or access cash, then quickly refinance with competitors looking to compete on better rates.

Recommendations:

- **Loan Structure Adjustments:** Implement 48-month maximum terms or 2% prepayment penalty in first 12 months for direct, used vehicles with >85% LTV approved through the automated approval system
- **Relationship Pricing for Retention:** Offer relationship and tenure-based pricing. Notify borrowers of possible interest rate reductions at 6 or 12 months to curb quick refinancing.
- **Underwriting Enhancement:** Build predictive model using internal data to identify refinance flight risk and adjust pricing accordingly

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Cluster 7: Direct New (5.29% - 2.3x baseline)

HIGH-END, HIGH-LTV FINANCE POOL - DIRECT NEW

The Profile: Prime credit customers (~750 average score) purchasing expensive vehicles ($75K average) with above-market loan-to-values. These customers finance maximum amounts to acquire high-end vehicles, then quickly refinance with competitors for better rates once the purchase is complete.

The Hidden Risk: All early payoffs (excluding 1) had an LTV of 95% or greater. In addition, all early payoffs (again, excluding 1) had an original balance of $65,000 or more. When this core group is isolated, the early payoff rate increases to 8.4%.

The Issue: Borrowers seek maximum financing (including negative equity coverage) for high-end new vehicles, then refinance to lower rates with competitors.

Recommendations:

- **Price In or Out Decision:** Institute 100+ bp premium for new vehicles >$65K with 95%+ LTV
- **Prepayment Protection:** Require 3% prepayment penalty in first 12 months for new loans >$65K with 95%+ LTV
- **Underwriting Policy:** Consider maximum 100% LTV cap on new vehicles and consider eliminating negative equity rollovers on high-value new

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Cluster 7: Indirect Used (5.45% - 2.3x baseline)

HIGH-END, HIGH-LTV FINANCE POOL - INDIRECT USED

The Profile: Nearly identical profile to the direct new borrowers. The differentiating factor is a higher average LTV (105%) and the indirect sourcing of the loan.

The Hidden Risk: All early payoffs (excluding 1) had an LTV of 100% or greater. In addition, all early payoffs had an original balance of $55,000 or more. When this core group is isolated, the early payoff rate increases to 18.5%.

The Problem: Again, borrowers seek maximum financing to refinance to lower rates with competitors. Think “bridge financing” at the dealership until they can secure better rates elsewhere.

Recommendations:

- **Price In or Out Decision:** Institute 100+ bp premium for indirect vehicles >$55K with 100%+ LTV
- **Dealer Rate Adjustment:** Reduce dealer reserve on high-balance, high-LTV used car loans as initial barrier
- **LTV Cap Implementation:** Maximum 100% LTV for indirect used loans >$55K (currently averaging 98.9%)

Cluster 9: Indirect New (6.54% - 2.8x baseline)

ULTRA-PRIME SMALL LOAN OPPORTUNISTS

The Profile: Elite credit customers making small purchases ($12K average) with substantial down payments (50% LTV). These are financially sophisticated and conservative buyers purchasing modest vehicles through dealer channels despite having the credit to finance anywhere. These are ideal borrowers with the safest loan structures (low LTV, small loans) but are actually the highest pay off risk.

The Hidden Risk: Maximum LTV for this cohort is 65% and the minimum score is 720. Nearly 75% of the early payoffs had a LTV of 40% or less.

The Problem: Maximum flexibility and zero urgency to stay with original financing. Dealer financing is merely “convenience” financing. These borrowers don't "need" our financing - they're using it tactically.

Recommendations:

- **Cost-Benefit Analysis:** Develop pricing model that accounts for early payoff risk, NOT just credit risk
- **Price In:** Reduce pricing by 75-100 bps for indirect loans at 50% LTV, 750+ credit score and loans < $20,000
- **Cross-Sell Opportunity:** Target this segment for deposit accounts, credit cards, and other products at loan origination. Think: Long-term value that exceeds single auto loan profitability

Part 4: Implementation Framework and Portfolio Optimization Monitoring

Strategic Action Framework

The analysis identified five critical customer segments driving the 2.76x acceleration in one-month early payoffs, representing the highest-priority intervention targets. Implementation should follow a phased approach balancing immediate risk mitigation with sustainable portfolio optimization.

Phase 1: Immediate Risk Mitigation (0-90 Days)

Focus on the two highest-risk segments with the most straightforward interventions:

- **Cluster 9/Indirect-New (6.54% payoff rate):** Implement relationship pricing strategy, reducing rates 75-100 basis points for ultra-prime customers (750+ credit, 50% LTV, loans <$20K). Simultaneously launch cross-sell initiative targeting deposit accounts and credit cards at loan origination to build relationship depth.
- **Cluster 7/Direct-New & Indirect-Used (5.29% and 5.45% payoff rates):** Institute prepayment penalties (2-3%) on high-LTV loans exceeding $55K-$65K thresholds. Implement LTV caps at 100% for new vehicles and used vehicles in these loan amount ranges. Consider limiting negative equity rollovers.

Expected Impact: 30-40% reduction in early payoffs within highest-risk segments, immediate improvement in portfolio yield retention.

Phase 2: Underwriting and Pricing Enhancement (90-180 Days)

Address segments requiring deeper analytics, model enhancements and dealer relationship adjustments:

- **Cluster 3/Direct-Used (4.10% payoff rate):** Build predictive scoring model using historical payoff patterns to identify refinance flight risk for automated approval customers. Adjust pricing algorithms to account for early payoff probability, not just credit risk.
- **Cluster 1/Indirect-New (4.49% payoff rate):** Negotiate dealer reserve reductions on super-prime new vehicle loans as initial barrier. Implement relationship-based rate reduction notifications at 6 and 12 months to preempt competitive refinancing.

Expected Impact: Risk-adjusted pricing improves margins while reducing adverse selection; dealer partnerships evolve to support retention objectives.

Phase 3: Deliberate Portfolio Repositioning (6-12 Months)

Long-term structural adjustments to portfolio composition and customer lifecycle management:

- Portfolio mix and segment optimization to balance credit and early payoff risk, in order to reduce concentration in ultra-high payoff risk segments
- Continued customer lifetime value modeling to understand, retain and guide underwriting cycles

Performance Monitoring Framework

Weekly Operational Tracking:

- One-month payoff rates by cluster-product combination, rate factor trends vs. 2.76x baseline, and intervention effectiveness metrics to measure impact of pricing adjustments, penalty implementation, and cross-sell/engagement rates

Monthly Portfolio Review:

- Cumulative payoff curves by origination quarter, portfolio composition shifts and concentration risk analysis. Also, incorporate dealer tracking by cluster-product segment

Quarterly Strategic Assessment:

- Forecast ROI analysis on retention interventions by segment. Build out customer lifetime value trends across clusters. Develop forecast economic scenario stress testing on prepayment assumptions