

# Notes for Real Estate Finance

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## Background

These are notes for US residential real estate finance. The document was created in RMarkdown with R plus a little L<sup>A</sup>T<sub>E</sub>X. TikZ (“TikZ ist kein Zeichenprogramm”) was used for the diagrams.

## Outline

### Money for Paper

At the most basic level, a home loan is a deal where borrowers give the lender a signed document (the promissory note) and the lender gives the borrowers money (Figure 1).

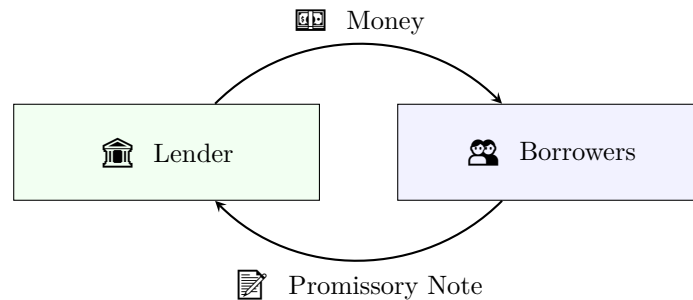


Figure 1: Money for Paper

The basics that apply to bonds or other types of debt also apply here: interest rates & discounts, calculating payment schedules, applying payments to principal and interest, etc. In a way, the loan part of a home loan is just an special kind of bond where, because of the right to **prepay**, the borrower is long a call option while the investor is short that borrower prepay option.

Refer to the **Loan** section of these notes for these basics about the loan as such.

## Money for Two Papers

They're called "home loans" for a reason: home loans use the subject property as collateral, so we have a second document involved (Figure 2).

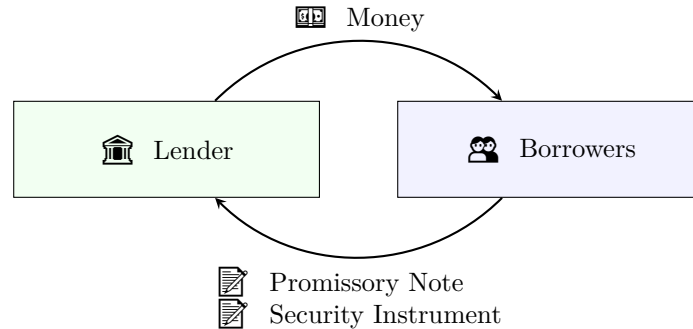


Figure 2: Money for Papers

This adds another dimension of complexity as each subject property has unique circumstances. We may need to involve the work of a professional appraiser to inspect the property and document collateral value via a 1004, 1073, etc. Additional state specifics come into play, e.g., New York CEMAs, Texas (a)(6). Servicing is more complex: the deal may include an escrow account for ensuring property hazard insurance premiums & real estate taxes are paid.

Adding collateral into the mix gives us Loan-to-Value (LTV), Combined Loan-to-Value (CLTV), and Home Equity Combined Loan-to-Value (HCLTV). That brings us to the topics of down payment and Mortgage Insurance (MI).

The security instrument itself could be a Mortgage, Deed of Trust, or Security Deed depending the state.

Refer to the [Collateral](#) section of this document for notes about collateral and related concepts.

## Money for Papers for Money

Where does the lender get money to lend, and what happens to the loan once originated? The lender may hold the loan on their books in portfolio, hopefully to earn net interest income which can be used for more loans, or they may sell the loan on the secondary market to get more money from the global pool of capital which can be used for more loans (Figure 3).

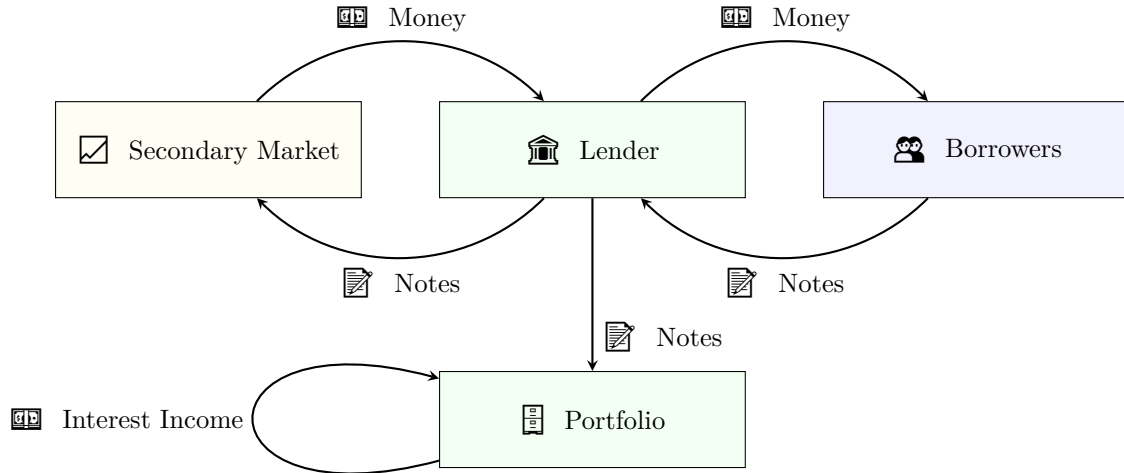


Figure 3: Money for Papers for Money

It's not simply a matter of selling the note. The loan might be pooled into a Mortgage-Backed Security (MBS), for example. Servicing might be retained or sold.

See [Secondary Market](#) for notes relevant to this cycle.

## Application Pipeline

It takes time to originate a home loan, hence the practice of locking in loan terms (including the interest rate) while the lender carries out underwriting and clears conditions ([Figure 4](#)).



Figure 4: Application Timeline

The pipeline varies depending on whether the application is taken directly (Retail), through a Broker (Wholesale), or through Correspondent Lending. Purchases have more steps than refinances.

Notes about the application process and all it entails are in the [App and Lock](#) section of this document.

## Loan

You can't have home loans without the "loan". At the most basic level, a home loan is a deal where borrowers give the lender a signed document (the promissory note) and the lender gives the borrowers money. The

promissory note documents the unconditional promise to repay the borrowed money. Generally the first section of the note will have language similar to the following.

In return for a loan in the amount of U.S. \$ \_\_\_\_ (the “Principal”) that I have received from \_\_\_\_ (the “Lender”), I promise to pay the Principal, plus interest, to the order of the Lender. I will make all payments under this Note in U.S. currency in the form of cash, check, money order, or other payment method accepted by Lender.

The two common ways to compensate the lender are interest and discount. For home loans there may or may not be some small discount amount at closing (see **Points**), plus origination fees to cover some of the costs of putting the deal together (see **App and Lock**), but for the most part the lender compensation is in the form of interest.

## Interest

The promissory note documents the interest charged and will include a clause similar to:

Interest will be charged on unpaid Principal until the full amount of the Principal has been paid. I will pay interest at a yearly rate of \_\_\_\_%.

Interest is specified as a yearly rate, then. Yet payments are not made annually:

I will pay principal and interest by making a payment every month. This amount is called my “Monthly Payment.” I will make my Monthly Payment on the first day of each month beginning on \_\_\_\_\_. I will make these payments every month until I have paid all of the Principal and interest and any other charges described below that I may owe under this Note. Each Monthly Payment will be applied as of its scheduled due date and will be applied to interest before the Principal.

Payments are done monthly, meaning we’ll need to do some interest rate conversion to line up the yearly interest rate with the monthly payments. As of 2026, the typical home loan calls for monthly payments on the first of the month. A *few* home loans are bi-weekly, the idea being to align the cadence of the payment with the cadence of how many people are paid (bi-weekly, often every other Friday).

The note will also contain language about paying the remaining balance, if any, which remains at maturity.

If, on \_\_\_\_\_, I still owe amounts under this Note, I will pay those amounts on that date, which is called the “Maturity Date.”

For a fixed-rate note we then see something along the lines of:

My Monthly Payment will be in the amount of U.S. \$ \_\_\_\_\_. This payment amount does not include any property taxes, insurance, or other charges that I may be required to pay each month.

Thus, for a fixed-rate home loan we’re expected to come up with some fully-amortizing monthly loan payment. How do we do that?

## Level Payments

Considerations for calculating a level fully-amortizing monthly loan payment for a fixed rate loan:

- Interest is in arrears, i.e., interest for a month is not due until the first of the following month.
- Interest rate is a constant annual rate all the way through to maturity.
- Interest rate is given as an annual rate, but payments will be monthly.

We can set this up as follows:

- Let  $L$  be our loan amount, i.e., the amount of unpaid principal financed as of closing.
- Let  $N$  be the term in months, e.g., 360 for a 30-year loan.
- Let  $r$  be our annual interest rate.
- Let  $P$  be our unknown monthly payment amount

Looking at it as we would an annuity, we need to restate our annual interest rate  $r$  as monthly rate  $\frac{r}{12}$ , which gives us a monthly discount factor for month number  $n$  of:

$$\left(\frac{1}{1 + \frac{r}{12}}\right)^n \quad n \in 1..N$$

Thus the ratio  $R$  from one month to another is:

$$R = \left(\frac{1}{1 + \frac{r}{12}}\right)$$

Then our loan ought to equal the following, which we recognize as a geometric series.

$$\begin{aligned} L &= \sum_{n=1}^N P \left(\frac{1}{1 + \frac{r}{12}}\right)^n \\ &= \sum_{n=1}^N PR^n \end{aligned} \quad \text{sub } R = \left(\frac{1}{1 + \frac{r}{12}}\right)$$

Solving for  $P$  we find:

$$\begin{aligned} L &= PR + PR^2 + \dots + PR^N \\ LR &= PR^2 + \dots + PR^N + PR^{N+1} && \text{multiply both sides by } R \\ LR - L &= PR^2 + \dots + PR^N + PR^{N+1} \\ &\quad - (PR + PR^2 + \dots + PR^N) && \text{difference} \\ &= PR^{N+1} - PR \\ L(R - 1) &= PR^{N+1} - PR && \text{factoring out } L \\ &= PR(R^N - 1) && \text{factoring out } PR \\ \frac{L(R - 1)}{R(R^N - 1)} &= P && \text{dividing by } R(R^N - 1) \end{aligned}$$

We could just cite properties of a geometric series to take some big shortcuts, but let's step through it instead. Looking at that expression, we can get some  $R$  cancellation if we first crack  $R$  back open in that numerator. Diving in to just that  $L(R - 1)$  numerator:

$$\begin{aligned} L(R - 1) &= L \left[ \left(\frac{1}{1 + \frac{r}{12}}\right) - 1 \right] && \text{definition of } R \\ &= L \left[ \left(\frac{1}{1 + \frac{r}{12}}\right) - \left(\frac{1 + \frac{r}{12}}{1 + \frac{r}{12}}\right) \right] \\ &= L \left( \frac{-\frac{r}{12}}{1 + \frac{r}{12}} \right) \\ &= -L \left( \frac{\frac{r}{12}}{1 + \frac{r}{12}} \right) && \text{pull out the minus sign} \\ &= -LR \frac{r}{12} && \text{sub } R \text{ back in} \end{aligned}$$

Then when we plug it back in we get the  $R$  cancellation and a tidy formula for the payment  $P$ .

$$\begin{aligned}
 P &= \frac{L(R-1)}{R(R^N-1)} \\
 &= \frac{-LR\frac{r}{12}}{R(R^N-1)} && L(R-1) = -LR\frac{r}{12} \\
 &= \frac{-L\frac{r}{12}}{R^N-1} && \text{cancellation} \\
 &= \frac{-L\frac{r}{12}}{R^N-1} \left(\frac{-1}{-1}\right) \\
 &= \frac{L\frac{r}{12}}{1-R^N} \\
 &= \frac{L\frac{r}{12}}{1-\left(\frac{1}{1+\frac{r}{12}}\right)^N} && \text{definition of } R \\
 &= \frac{L\frac{r}{12}}{1-\left(1+\frac{r}{12}\right)^{-N}}
 \end{aligned}$$

If we let  $M = \frac{r}{12}$  (“M” as in “Monthly Rate”) we can express this more concisely:

$$\begin{aligned}
 P &= \frac{L\frac{r}{12}}{1-\left(1+\frac{r}{12}\right)^{-N}} \\
 &= \frac{L \cdot M}{1-\left(1+M\right)^{-N}} && \text{let } M = \frac{r}{12}
 \end{aligned}$$

Some final considerations:

- If the monthly rate is zero we simply have  $N$  equal payments.
- For a loan to exist we require:
  - a positive loan term
  - a non-negative loan amount
  - monthly rate can’t be -100% or less

Why can’t we have a monthly rate of -100%? A “loan” with immediate 100% forgiveness of the amount borrowed is just a gift.

The upshot:

$$P = \begin{cases} \frac{L \cdot M}{1-(1+M)^{-N}} & M \neq 0 \\ \frac{L}{N} & M = 0 \end{cases} \quad \text{where } N > 0, L \geq 0, M > -1$$

In R the  $M \neq 0$  case is `PrinBal * PerPeriodRate / (1 - (1 + PerPeriodRate)^(-PeriodCnt))`. Let’s code that in an R function.

```

# Calculate the fully amortizing constant periodic payment
CalcAmortPmt <- function(PrinBal, PerPeriodRate, PeriodCnt) {

  # Check for valid PeriodCnt: we need at least 1 period.
  if (PeriodCnt <= 0) {
    stop("PeriodCnt must be positive")
  }
}

```

```

# Check for valid PrinBal: it cannot be negative.
if (PrinBal < 0) {
  stop("PrinBal must be non-negative")
}

# Check for valid PerPeriodRate: it cannot be -100% or lower.
if (PerPeriodRate <= -1) {
  stop("PerPeriodRate must be greater than -100%")
}

# If no interest, simply divide the loan evenly by number of payments
if (PerPeriodRate == 0) {
  return(PrinBal / PeriodCnt)
}

# Apply the level payment formula (i.e., the M != 0 case)
return(PrinBal * PerPeriodRate / (1 - (1 + PerPeriodRate)^(-PeriodCnt)))
}

```

We can rearrange our formula for  $P$  to move  $L$  to the left hand side and  $P$  to the right hand side. Now with  $L$  being the output we can relax the  $P \geq 0$  requirement to permit negative or zero results and allow  $M = -1$  (outcomes which are not loans).

$$L = \begin{cases} P \cdot \frac{1 - (1 + M)^{-N}}{M} & M \neq 0 \\ P \cdot N & M = 0 \end{cases} \quad \text{where } N > 0, M \geq -1$$

We'll likewise code that up in an R function.

```

# Calculate the principal given a fully amortizing constant periodic payment
CalcAmortPrinBal <- function(Pmt, PerPeriodRate, PeriodCnt) {

  # Check for valid PeriodCnt: we need at least 1 period.
  if (PeriodCnt <= 0) {
    stop("PeriodCnt must be positive")
  }

  # Check for valid PerPeriodRate: it cannot be lower than -100%.
  if (PerPeriodRate < -1) {
    stop("PerPeriodRate must be at least -100%")
  }

  # If no interest, principal is just total payments
  if (PerPeriodRate == 0) {
    return(Pmt * PeriodCnt)
  }

  # Apply inverse amortization formula for M != 0
  return(Pmt * (1 - (1 + PerPeriodRate)^(-PeriodCnt)) / PerPeriodRate)
}

```

Seems straightforward, but we're forgetting something: monthly payments cannot be made in fractions of a penny. How do we make this work?

## Pennies and the Final Payment

If we actually try to use `CalcAmortPmt` we run into the issue that monthly payments cannot be made in fractions of a penny, so we will have to round the actual payment amount  $P_{USD}$  to the penny as follows.

$$P_{USD} = \begin{cases} \frac{1}{100} \left[ 100 \cdot \frac{L \cdot M}{1 - (1+M)^{-N}} + \frac{1}{2} \right] & M \neq 0 \\ \frac{L}{N} & M = 0 \end{cases} \quad \text{where } N > 0, L \geq 0, M > -1$$

This need to round to pennies introduces two rounding discrepancies: one from the rounding of the payment each month, the other due to the rounding of interest each month. Consequently, the very last payment may need to be reduced, or we may have a small balance left over after the last scheduled payment. We can illustrate that with an example by calculating an actual amortization table. Let's code that up in R with the results as a `data.table`.

```
library(data.table, quietly=TRUE)
```

Sketching out a plan for the amortization table function, we want inputs:

- `PrinBal` for the principal balance
- `InterestRate` for the interest rate
- `TermMonths` for the term in months

Then the amortization table should include:

- `MonthNum`, e.g., 1 for the first month, 360 for the last month of a 30-year
- `StartingUPB` for the unpaid principal balance (UPB) at the start of that month
- `InterestAmt` for the amount of interest owed for that month
- `PIAmt` for the amount of principal and interest paid, i.e., our fixed payment  $P$
- `EndingUPB` for the new UPB after applying the payment to UPB and interest owed

For the final month we need to reduce the payment if it would have exceeded the amount owed.

If at the final month a balance is still owed we can either add it to the final payment or just indicate that balance. For our purposes here perhaps it's better to indicate the balance.

It's straightforward to code this in R. The built-in function `round()` will round exactly as we require.

```
# Construct data.table having MonthNum, StartingUPB, InterestAmt, PIAMt, EndingUPB
CalcAmortTable <- function(PrinBal, InterestRate, TermMonths) {

  # Ensure UPB has no fractions of a penny
  PrinBal <- round(PrinBal, 2)

  # Calculate a monthly interest rate
  MonthlyRate <- InterestRate / 12

  # Calculate our level payment, taking care to round to the penny as we cannot
  # transact fractions of a penny.
  PmtAmt <- round(CalcAmortPmt(PrinBal, MonthlyRate, TermMonths), 2)

  # Construct an amortization schedule using a data.table
  tAmort <- data.table(
    MonthNum = 1:TermMonths,
```

```

StartingUPB = 0.0,
InterestAmt = 0.0,
PIAmt = 0.0,
EndingUPB = 0.0
)

# Populate the amortization schedule, taking care to round to the penny
# as we cannot transact fractions of a penny.
bal <- PrinBal
for (i in 1:TermMonths) {

  # Starting UPB for this month is the ending UPB from last month
  set(tAmort, i, "StartingUPB", bal)

  # Interest owed for this month is UPB times the monthly rate
  int <- round(bal * MonthlyRate, 2)
  set(tAmort, i, "InterestAmt", int)

  # Payment for this month (last month may need adjusting)
  pmt <- min(PmtAmt, bal + int)
  set(tAmort, i, "PIAmt", pmt)

  # Ending UPB for this month is UPB plus interest minus payment
  upb <- bal + int - pmt
  set(tAmort, i, "EndingUPB", upb)

  # Next month's starting balance
  bal <- upb
}

# return the table
return(tAmort)
}

```

Now to exercise the code, let's use the median home sales price from Irvine as of March 2026.

```

# Median home sales price in March 2026 was 1,510,000 for Irvine, use that
# with a 20% down payment to set our example loan amount
PrinBal <- 1510000 * 0.8
InterestRate <- 0.05
TermMonths <- 30 * 12

```

Then to try it out.

```

tAmort <- CalcAmortTable(PrinBal, InterestRate, TermMonths)
tAmort[] # print first few and last few entries

```

```

##      MonthNum StartingUPB InterestAmt   PIAmt EndingUPB
##      <int>      <num>      <num>   <num>   <num>
##  1:         1  1208000.00    5033.33  6484.81 1206548.52
##  2:         2  1206548.52    5027.29  6484.81 1205091.00
##  3:         3  1205091.00    5021.21  6484.81 1203627.40
##  4:         4  1203627.40    5015.11  6484.81 1202157.70

```

```
## 5:      5 1202157.70    5008.99 6484.81 1200681.88
## ---
## 356:    356  32018.62    133.41 6484.81  25667.22
## 357:    357  25667.22    106.95 6484.81  19289.36
## 358:    358  19289.36     80.37 6484.81  12884.92
## 359:    359  12884.92     53.69 6484.81   6453.80
## 360:    360   6453.80     26.89 6480.69    0.00
```

The last two rows show that the discrepancy due to rounding was very small in this case.

We can calculate the payment rounding difference  $\epsilon_{Pmt}$  by applying the future value formula to the difference of the rounded  $P_{USD}$  and unrounded  $P$ . Then for the interest rounding difference  $\epsilon_{Int}$  we can total up each of the monthly differences. Let's compare the actual discrepancy with those calculations.

```
# Get the discrepancy amount for the last payment; negative means balance owed.
GetAmortTableLastPmtDiffAmt <- function(tAmort) {
  EndIdx = nrow(tAmort)
  EndingUPB = tAmort$EndingUPB[EndIdx]
  if (EndingUPB > 0 || EndIdx==1) {
    return(EndingUPB)
  }
  return(tAmort$PIAmt[EndIdx] - tAmort$PIAmt[EndIdx-1])
}

# Get actual observed discrepancy amount
DiffAmt <- GetAmortTableLastPmtDiffAmt(tAmort)

# exact theoretical payment
MonthlyRate <- InterestRate / 12
ExactPmtAmt <- CalcAmortPmt(PrinBal, MonthlyRate, TermMonths)

# Rounded actual payment
PmtAmt <- round(ExactPmtAmt, 2)

# Exact payment-rounding contribution, i.e., FV of the differences
EpsPmtAmt <- CalcAmortPrinBal(ExactPmtAmt - PmtAmt, MonthlyRate, TermMonths) *
  (1+MonthlyRate)^TermMonths

# Exact interest-rounding contribution
eps <- tAmort$InterestAmt - (tAmort$StartingUPB * MonthlyRate)
EpsIntAmt <- sum(
  eps * (1 + MonthlyRate)^((TermMonths:1) - 1)
)

# Combined errors
EstDiffAmt <- EpsPmtAmt + EpsIntAmt

# Comparison
sprintf("Estimated discrepancy was %.2f, actual observed was %.2f",
  EstDiffAmt, DiffAmt)
```

```
## [1] "Estimated discrepancy was -4.12, actual observed was -4.12"
```

They tie to the penny.

Concerning this line of code:

```
# Exact payment-rounding contribution, i.e., FV of the differences
EpsPmtAmt <- CalcAmortPrinBal(ExactPmtAmt - PmtAmt, MonthlyRate, TermMonths) *
(1+MonthlyRate)^TermMonths
```

Calling `CalcAmortPrinBal()` is finding the loan amount, i.e., the PV (Present Value) of the payments, but here we needed the final residual dollar amount, i.e., the FV (Future Value), so we've simply multiplied by  $(1+MonthlyRate)^{TermMonths}$  to make the conversion. Home loan payment calculations are just another flavor of annuity calculation, so all the PV and FV formulas from annuities and perpetuities carry over to home loans. Bottom line is we convert using the discount rate. Aswath Damodaran gives a nice definition of discount rate as:

the rate used to move cash flows from the future to the present, in discounting, or from the present to the future, in compounding.

The first example we tried had a smaller final payment. Let's try one where we have a balance left over after the final payment. We'll use the median home sales price from San Diego as of March 2026.

```
# Median home sales price in March 2026 was 950,000 for San Diego, use that
# with a 20% down payment to set our second example loan amount
PrinBal <- 950000 * 0.8
InterestRate <- 0.05
TermMonths <- 30 * 12
```

As before we'll print the first few and last few rows.

```
tAmort <- CalcAmortTable(PrinBal, InterestRate, TermMonths)
tAmort[] # print first few and last few entries
```

```
##      MonthNum StartingUPB InterestAmt   PIAmt EndingUPB
##      <int>      <num>      <num>   <num>   <num>
##  1:         1   760000.00    3166.67  4079.84  759086.83
##  2:         2   759086.83    3162.86  4079.84  758169.85
##  3:         3   758169.85    3159.04  4079.84  757249.05
##  4:         4   757249.05    3155.20  4079.84  756324.41
##  5:         5   756324.41    3151.35  4079.84  755395.92
##  ---
## 356:       356    20150.21      83.96  4079.84   16154.33
## 357:       357    16154.33      67.31  4079.84   12141.80
## 358:       358    12141.80      50.59  4079.84    8112.55
## 359:       359     8112.55      33.80  4079.84    4066.51
## 360:       360     4066.51      16.94  4079.84     3.61
```

Once again the discrepancy due to rounding was very small. The clause in the promissory note about paying the remaining balance which remains at maturity would kick in on this one, so the last payment would be adjusted up to clear that balance.

What kind of differences do we see at a typical (as of 2026) loan amount and interest rate? Let's try 40,000+ combinations of loan amount and interest rate to see what kinds of differences arise for loan amounts around \$700,100 and interest rates around 5%. We'll vary interest rate in 1 basis point increments, loan amount in \$1 increments.

```

tScenario <- CJ(
  PrinBal = seq(700001, 700201, by=1),
  InterestRate = seq(0.040, 0.06, by = 0.0001)
)
tScenario[, DiffAmt:= NA_real_]
tScenario[, DiffPct:= NA_real_]
tScenario[, DiffContribPmtPct:= NA_real_]

for (i in seq_len(nrow(tScenario))) {

  # Load scenario
  PrinBal <- tScenario$PrinBal[i]
  InterestRate <- tScenario$InterestRate[i]

  # Calculate the amortization table
  tAmort <- CalcAmortTable(PrinBal, InterestRate, TermMonths)

  # Get the difference amount and log it
  Amt <- GetAmortTableLastPmtDiffAmt(tAmort)
  tScenario[i, DiffAmt:=Amt]

  # Get the level payment amount and log the diff as a pct of the level pmt
  PIAmt <- tAmort$PIAmt[1]
  tScenario[i, DiffPct:=Amt/PIAmt]

  # Find the exact level payment amount
  MonthlyRate <- InterestRate / 12
  ExactPmtAmt <- CalcAmortPmt(PrinBal, MonthlyRate, TermMonths)

  # Find the payment rounding contribution to the discrepancy and log
  # it as a % of the level payment amount
  EpsPmtAmt <- CalcAmortPrinBal(ExactPmtAmt - PIAmt, MonthlyRate, TermMonths) *
    (1+MonthlyRate)^TermMonths
  tScenario[i, DiffContribPmtPct:=EpsPmtAmt/PmtAmt]
}

```

What kind of differences did we get?

```
summary(tScenario$DiffAmt)
```

```
##      Min.   1st Qu.   Median     Mean   3rd Qu.    Max.
## -5.230000 -2.090000  0.000000 -0.006418  2.060000  5.380000
```

All very small. We can visualize using ggplot with help from patchwork and viridis.

```

library(ggplot2, quietly=TRUE)
library(viridis, quietly=TRUE)
library(patchwork, quietly=TRUE)

```

We'll plot the % differences, i.e., the discrepancy amount as a % of the level payment. We have two independent variables, so we'll go with a heatmap using `geom_tile()` with the difference in last payment amount as a % of the level payment amount in left plot and the payment amount rounding contribution to

the discrepancy as a % of the level payment amount in the right plot. The `patchwork` library permits this kind of side-by-side. First we build the left plot:

```
# Final payment difference as a % of the level payment
p1 <- ggplot(tScenario,
  aes(
    x = InterestRate,
    y = PrinBal,
    fill = DiffPct
  )
) +
geom_tile() +
scale_fill_viridis(
  discrete=FALSE,
  option="inferno",
  labels = function(x) sprintf("%+3.2f%%", 100 * x)
) +
scale_x_continuous(labels = function(x) sprintf("%3.2f%%", 100 * x)) +
labs(
  title = "Final Payment Difference",
  subtitle = "(% of Level Payment)",
  x = "Interest Rate",
  y = "Principal ($)",
  fill = "Diff (%)"
) +
theme_minimal(base_family = "mono")
```

Some explanation for the `labels = function(x) sprintf("%+3.2f%%", 100 * x)` lines. Labels expect a function on legend break values that returns character strings for display. The `labels = function(x)` part is supplying an anonymous function, i.e., we're telling `ggplot` "whenever you need labels, call this function on the vector of break values". It's like what Python calls lambda functions (but not limited to a single expression). Concerning the multiplication by 100: `DiffPct` is stored as a decimal fraction, e.g., 0.05 for 5%, but it reads better here to express these small values in percentage terms, hence the `100 * x` part. Then breaking down the format string of `sprintf` (i.e., the first argument), the `"%+3.2f%%"` includes:

- the introductory % character (just as with `sprintf` format strings in C)
- the + in `%+3.2f` says to always prepend the sign
- the 3 is the minimum field width
- the `.2f` is the precision of the conversion, i.e., two decimals
- final %% because we quote the % with another % to get literal %

Upshot is we get easier to read strings like "+0.05%" for 0.0005 and "-0.05%" for -0.0005.

Then the right plot—no need to repeat the y-axis:

```
# Payment amount rounding contribution to the final payment discrepancy as
# a % of the level payment amount
p2 <- ggplot(tScenario,
  aes(
    x = InterestRate,
    y = PrinBal,
    fill = DiffContribPmtPct
  )
) +
```

```

geom_tile() +
scale_fill_viridis(
  discrete=FALSE,
  option="viridis",
  labels = function(x) sprintf("%+3.2f%%", 100 * x)
) +
scale_x_continuous(labels = function(x) sprintf("%3.2f%%", 100 * x)) +
labs(
  title = "Payment Rounding Contribution",
  subtitle = "(% of Level Payment)",
  x = "Interest Rate",
  y = "Principal ($)",
  fill = "Diff (%)"
) +
theme_minimal(base_family = "mono") +

# We only need the leftmost y-axis
theme(axis.text.y = element_blank(),
      axis.ticks.y = element_blank(),
      axis.title.y = element_blank())

```

We use | to tell patchwork we want the plots to be side-by-side (it would have been / to stack them top-to-bottom).

```

# Side-by-side
(p1 | p2) + plot_layout(guides = "collect") & theme(legend.position = "right")

```

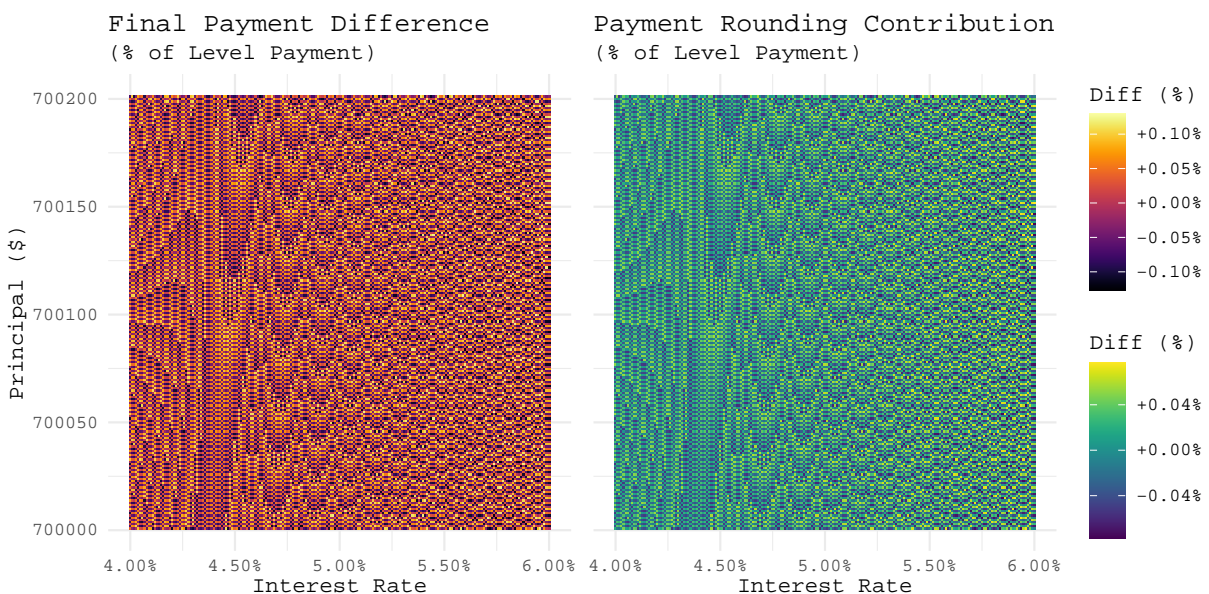


Figure 5: Final Payment Difference

Is there a pattern?

In any case, we can see that the discrepancy due to rounding is consistently much smaller than the level payment amount. Either the last payment will be slightly less than the other payments, or there will be a small balance left over leading to a slightly higher last payment.

Mission accomplished: we can calculate a nearly perfect level payment so that each monthly payment is identical other than a small difference at the end. But what happens at the other end of the loan—at the very beginning—if we don't disburse funds on exactly the first of the month? The answer is that most loans have an initial partial month of interest due at closing.

## Daily Interest (First Partial Month)

Home loans usually have a partial month of interest paid at closing. For example, if the promissory note and other docs were signed Tuesday May 5, 2026 with funds disbursed Thursday May 7, 2026, then more than likely our first payment due date is not until July 1, 2026, so at closing we would see payment of the 25 days of interest in May.

```
as.Date("2026-06-01") - as.Date("2026-05-07")
```

```
## Time difference of 25 days
```

The basis for daily interest is typically a 365-day year, thus yielding the following formula for one-time payment  $P$  from loan amount  $L$  number of days  $D$  and annual rate  $r$ .

$$P = L \cdot D \cdot \left( \frac{r}{365} \right)$$

This means that it's a little cheaper for the borrower to close in February, there being one, two, or three fewer days in February than in other months. To illustrate, let's return to that March 2026 median home sales price for Irvine example.

```
# Median home sales price in March 2026 was 1,510,000 for Irvine, use that
# with a 20% down payment to set our example loan amount
PrinBal <- 1510000 * 0.8
InterestRate <- 0.05
TermMonths <- 30 * 12

# Monthly Interest Rate
MonthlyRate <- InterestRate / 12

# Daily Interest Rate
DailyRate <- InterestRate / 365

# Examples for two months of interest
cat(
  "Interest scenarios:\n",
  sprintf(" $%9.2f under simple interest for Feb 2026 + monthly for Mar",
    PrinBal * 28 * DailyRate + PrinBal * MonthlyRate),
  "\n",
  sprintf(" $%9.2f under simple interest for Mar 2026 + monthly for Apr",
    PrinBal * 31 * DailyRate + PrinBal * MonthlyRate),
  "\n",
  sprintf(" $%9.2f under simple interest for Apr 2026 + monthly for May",
    PrinBal * 30 * DailyRate + PrinBal * MonthlyRate),
  "\n"
)
```

```
## Interest scenarios:
## $ 9666.76 under simple interest for Feb 2026 + monthly for Mar
## $ 10163.20 under simple interest for Mar 2026 + monthly for Apr
## $ 9997.72 under simple interest for Apr 2026 + monthly for May
```

So we've seen how to handle interest in the initial partial month, and we've shown how to calculate the fully amortizing level payment, but what happens if the borrower makes a payment ahead of the fully amortizing payment schedule? This gets into the topic of prepayments.

## Prepayments

Borrower repayment of principal before the due date is known as prepayment. The relevant section of a promissory note may have something similar to the following language:

I have the right to make payments of principal at any time before they are due. A payment of principal only is known as a "Prepayment." When I make a Prepayment, I will notify the Note Holder in writing that I am doing so. I may not designate a payment as a Prepayment if I have not made all the Monthly Payments then due under this Note.

Some promissory notes include a prepayment penalty to recoup the lender some of the interest they had expected to earn when the loan was made. Other notes have no prepayment penalties, instead baking prepayment into the total cost of the loan. A typical (as of 2026) note has no prepayment penalty per a clause which reads something like:

I may make a full Prepayment or partial Prepayments without paying a Prepayment charge. The Note Holder will use my Prepayments to reduce the amount of Principal that I owe under this Note. However, the Note Holder may apply my Prepayment to the accrued and unpaid interest on the Prepayment amount, before applying my Prepayment to reduce the Principal amount of the Note. If I make a partial Prepayment, there will be no changes in the due date or in the amount of my Monthly Payment unless the Note Holder agrees in writing to those changes.

Borrowers may exercise their prepayment right for a number of reasons.

- rate & term refinancing so borrower benefits from lower interest rates
- borrower is selling the property, for example due to relocating
- partial prepayment as a form of savings

A prepayment may also occur not because the borrower exercised their right but because the collateral was sold off after the borrower defaulted (see [Collateral](#)).

Regardless of the reason, any payments to principal received in excess of the repayment schedule meet the definition of prepayment. Prepayments affect the cash flow to the owner of the note (whether held whole loan, in an MBS, or other security) and thus the valuation. In a sense, the borrower is long a call option while the investor is short that borrower prepay option. Given that prepayments can reduce yield, how do we measure and manage that prepayment risk?

## SMM and CPR

The simplest way to model prepayment speed is using single monthly mortality (SMM) and annualized constant prepayment rate (CPR), also known as conditional prepayment rate or constant conditional prepayment rate. SMM measures prepayment as the amount prepaid during a single month expressed as a

percentage of the expected scheduled outstanding balance. If  $UPB$  is our actual unpaid principal balance and  $UBP_{sched}$  is our scheduled unpaid principal balance, then  $SMM$  is:

$$SMM = \frac{UBP_{sched} - UPB}{UBP_{sched}}$$

It follows then that  $1 - SMM$  is the proportion of the scheduled UPB that survives, which if we assume a constant prepayment rate means that after 12 months we have  $(1 - SMM)^{12}$  surviving versus  $1 - (1 - SMM)^{12}$  prepaid. CPR is this annualized constant prepayment rate:

$$CPR = 1 - (1 - SMM)^{12}$$

$SMM$  and  $CPR$  have a geometric relationship, so if we wanted a  $CPR$  for some period of time other than 1 year, say  $k$  months, then our  $k$ -month  $CPR$  would be:

$$\begin{aligned} k\text{-month } CPR &= 1 - \prod_{i=1}^k (1 - SMM_i) \\ &= 1 - (1 - SMM)^k \end{aligned} \quad \text{\textit{SMM constant over all } } k \text{ months}$$

If we wanted to annualize that  $k$  month  $CPR$ —let’s call it  $CPR_k$ —then we would use:

$$\begin{aligned} CPR_k &= 1 - \left( \prod_{i=1}^k (1 - SMM_i) \right)^{\frac{12}{k}} \\ &= 1 - ((1 - SMM)^k)^{\frac{12}{k}} \end{aligned}$$

Working in the other direction, if we started with  $CPR$  then  $SMM$  could be found using:

$$SMM = 1 - (1 - CPR)^{\frac{1}{12}}$$

So  $CPR$  and  $SMM$  measure prepayment. Do we really just characterize prepayment with a single number, though—are prepayment speeds really more or less constant?

## PSA

In practice, prepayment speeds are not constant. Instead, they tend to ramp up over time. PSA is the Securities Industry and Financial Markets Association (SIFMA) standard prepayment model. A standard assumption (“100% PSA”) is that mortgages prepay at an annual rate of 0.2% in the first month after origination, increasing by an annual rate of 0.2% per month up to the 30th month, then sit at a constant 6% per year in the 30th and later months. This can be adjusted: 200% PSA would be 2.0 times the 100% PSA while 50% is 0.5 times the 100% PSA. 0% would assume no prepayments.

## Prepayment Models

$CPR$  and  $SMM$  measure prepayment speed while  $PSA$  provides a standardized benchmark curve. On their own, neither  $PSA$  nor  $CPR$  describe actual prepayment experience since so many other factors influence prepayment. Lenders, investors, servicers, and other market players all model prepayment, producing “prepayment curves” and other estimates of prepayment as a function of many variables.

Loan age matters since prepayments tend to ramp up as the loan “seasons” (as discussed above). It’s unusual to take out a home loan and pay it off right away.

Refinancing incentive is a very important input: prepayments exhibit a clear “S-curve” when plotting  $CPR$  against refi incentive. The refi incentive is the spread between the note rate and the rate that could be

obtained today. Thus higher interest rate environments tend to slow prepayments, whereas a drop in interest rates can trigger a spike in rate & term refinances (“refi boom”).

An increase in collateral values tends to increase prepayments, especially to the extent that loans cross below 80% LTV (see [Collateral](#)). The flip side of this is that a decrease in collateral values may slow prepayments (though perhaps too big of a drop leads to “strategic defaults” and thus higher prepayment).

Some less obvious factors include seasonal effects (home buying being most active in the summer) and the burnout effect (more refi sensitive borrowers exit earlier).

## Escrows

The monthly **level payment** included principal and interest. In practice, monthly payments often include additional items paid into escrow accounts separate from the loan.

The purpose of escrows is to ensure that taxes, insurance premiums, and other property-related obligations are paid when due, thereby protecting the collateral. An example is property taxes since, if the borrower doesn’t pay property taxes owed, the collateral could be auctioned off with the government getting their due first. The full monthly payment of principal, interest, taxes, and insurance is referred to as PITI or in some contexts as PITIA (the “A” being for association dues).

Escrowed items may include:

- hazard insurance
- borrower-paid mortgage insurance
- property taxes

Hazard insurance covers loss of the home due to fire or other hazards and protects both the lender and the borrower. Flood insurance may be a separate item.

Mortgage insurance protects the lender in the event of borrower default (see [Mortgage Insurance](#)).

Property taxes are imposed by local taxing authorities (based on where the subject property is located). Each tax authority has their own way they want things done. It varies by jurisdiction, but perhaps the most common scenario is annual assessments assessed and collected at the county level. The actual bill may contain a mix of taxes and assessments, e.g., a base tax set at the state level, a tax for the school district, a tax for water based on the municipality, an assessment for vector control for the county. The assessments may be annual but the payments split to be semi-annual or other payment frequency.

Escrows are not universal. Some lenders permit escrow waivers, allowing borrowers to pay taxes and insurance directly rather than through an escrow account.

Escrows are implemented via escrow accounts that the servicer establishes or controls on behalf of a borrower to pay taxes, insurance premiums, etc. These are also known as impound accounts. Escrow accounts are set up at closing. Before establishing the escrow account, an escrow account analysis is carried out to determine the amount the borrower must deposit into the escrow account at closing—the amount should be large enough to cover obligations but not so large as to run afoul of RESPA regulations. The initial escrow deposit is itemized on lines 1001-1006 of the HUD-1 or section G of “Other Costs” of the newer Closing Disclosure.

The servicer collects escrow payments each month and pays the various insurers and local governments as payments become due (the borrower is making monthly contributions to the escrow account, whereas the expenses may be quarterly, semi-annually, annually, etc.). The goal is to have enough of a balance to pay items as they come due, plus a small cushion to soften any increase in required payments. Per RESPA / Reg X 12 C.F.R. § 1024.17 part (c):

... the servicer may charge the borrower a cushion that shall be no greater than one-sixth (1/6) of the estimated total annual payments from the escrow account.

Upshot is the servicer is targeting a balance equal to 14 months of payments (12 months plus 1/6 of 12 months).

Some states require that escrow accounts be interest-bearing, meaning the borrower could be earning interest income from the balance on the escrow account.

The servicer regularly reanalyzes escrow requirements to dial the total payment up or down as needed, keeping in mind that insurance premiums and property taxes can vary from year to year, for example due to property taxes increasing. The servicer may even identify an escrow shortage significant enough to require a lump-sum payment to make up the difference. Conversely, the servicer may identify an escrow surplus large enough to result in a refund to the borrower, along with a reduction in monthly payments.

Thus, the total monthly payment for a fully amortizing level-payment fixed-rate home loan can nonetheless vary over time due to the need to account for changing insurance premiums and property taxes. Some types of home loan have non-level payments built into the loan structure (**Non-level Payments**).

## Non-level Payments

An adjustable rate mortgage (ARM) has an interest rate which is not fixed through to maturity. Instead, the interest rate floats versus some agreed-upon index with the interest rate and required monthly payment amount adjusted accordingly.

Most ARMs are Hybrid ARMs, meaning there is an initial fixed-rate period followed by a floating period. ARMs normally have caps which limit changes in interest rate. For example, a 7/1 5-2-5 hybrid ARM has:

- an initial fixed period of 7 years
- change rate adjustment frequency of 1 year, i.e., adjustments at years 5, 6, 7, ...
- with 5-2-5 caps, meaning:
  - initial cap of 5%, i.e., first adjustment cannot increase interest rate by more than 5% (absolute)
  - subsequent cap of 2%
  - lifetime cap of 5%

If the subsequent frequency is given as “6”, e.g., a 7/6, it indicates 6-months between change dates, not 6 years. Example language from the note:

The interest rate I will pay may change on the first day of \_\_\_\_\_, and on the first day of the month every 6th month thereafter. Each date on which my interest rate could change is called a “Change Date.”

Variable Rate Mortgage (VRM) is a very old name for ARMs.

## ARM Index

The ARM index, for example 30-day average SOFR, is the basis for adjusting the interest rate. The margin plus the index gives the fully indexed rate.

The lookback period specifies the number of days preceding the rate adjustment effective date to look back for the index value, e.g., 45 days. This may be given as the interest and payment adjustment index lead days count.

The floor rate is the lowest possible rate—if not given, the convention is the floor is the margin.

The promissory note will include details for the index and lookback.

The following is example language for 30-day average SOFR with a 45-day lookback.

Beginning with the first Change Date, my interest rate will be based on an Index that is calculated and provided to the general public by an administrator (the “Administrator”). The “Index” is a benchmark, known as the 30-day Average SOFR index. The Index is currently published by the Federal Reserve Bank of New York. The most recent Index value available as of the date 45 days before each Change Date is called the “Current Index,” provided that if the Current Index is less than zero, then the Current Index will be deemed to be zero for purposes of calculating my interest rate

Adjustments are typically subject to rounding, e.g., round to nearest 0.125 (nearest eighth). Rounding should be indicated in the note as part of the calculation of changes, for example:

Before each Change Date, the Note Holder will calculate my new interest rate by adding a margin of percentage points (\_\_\_\_%) to the Current Index. The Note Holder will then round the result of this addition to the nearest one-eighth of one percentage point (0.125%).

### **IOs, Balloons, Neg Am, Pay Option, GPMs**

A loan—whether fixed or ARM—that does not fully amortize but instead leaves a very large final amount due at maturity is called a balloon. The final payment is referred to as the balloon payment.

Interest Only (IO) loans are when the loan calls only for payment of interest—no principal—for a lengthy period of time, for example the first 10 years of a 30-year loan. Once the IO period ends, the payment amount increases so as to amortize in full by maturity.

Another historical arrangement was to permit negative amortization (“neg am”), meaning the borrower at times pays less than the interest owed. Any payment adjustment frequency less than the rate adjustment frequency implies that negative amortization is possible.

Pay Option loans often permitted the borrower to make a fully amortizing payment, interest only payment, or a neg am payment, subject to timing and other guardrails. Some pay option ARMs had introductory rates, for example during the first year, which when combined with neg am payments could lead to “payment shock” once the introductory rate ended.

Historically, a Graduated Payment Mortgage (GPM) was a type of mortgage with a payment that started smaller then increased over the life of the loan. They permitted neg am but compensated by requiring larger than usual down payments. These were first tested by the FHA (see [FHA](#)). GEMs (Growing Equity Mortgages) were another similar deal but did not permit neg am.

### **HELOCs, CESs, Reverse mortgages**

HELOCs are Home Equity Lines of Credit, i.e., lines of credit that use the home as collateral. Features:

- line amount
- initial draw amount, i.e., the amount drawn at closing
- draw period, e.g., 10 years
- repayment period, e.g., 20 years

HELOC interest is typically calculated by multiplying the average daily balance during the billing cycle by the daily interest rate (usually  $\frac{r}{365}$ , see [Daily Interest](#)). As with ARMs, there will be some index plus a margin.

HELOC payment due dates vary by lender. Unlike first mortgages, HELOC payment due dates may not be the first of the month.

Some HELOCs may have the line frozen, meaning no further draws are permitted, even during the draw period.

No further draws are made during the repayment period; instead, the borrower pays down the balance.

Closed-end seconds (CES), sometimes called home equity loans, are just term loans in the second lien position (see [Lien](#)). Normally these are fixed interest, especially those marketed as home equity loans. Fixed interest CESs are also known as “Fixed Rate Seconds”. Many down payment assistance programs are implemented via closed-end seconds, for example with deferred payments or in an arrangement where the balance is gradually forgiven per some schedule (but with balance due in the event of an early sale of the property or other triggering event).

Reverse mortgages are an arrangement where the homeowner receives payments from the lender (“loan advances”). An example reverse mortgage is the FHA Home Equity Conversion Mortgage (HECM). Homeowners at least 62 years of age receive payments over time while retaining ownership of the property. Example promissory note language:

In return for amounts to be advanced by the Lender to or for the benefit of the Borrower under the terms of the Loan Agreement, the Borrower promises to pay to the order of the Lender a principal amount equal to the sum of \$ \_\_\_\_\_ and all Loan Advances made under the Loan Agreement with interest. Interest will be charged on unpaid principal at the rate of \_\_\_ percent (%) per year until the full amount of principal has been paid. Accrued interest shall be added to the Principal Balance as a Loan Advance at the end of each month.

Reverse mortgage payments to the borrower may be set up in a few ways:

- Tenure, where borrowers receive payments as long as they occupy the home
- Term, where payments are for a fixed term
- Line of credit
- Modified tenure = tenure + line of credit
- Modified term = term + line of credit

The reverse mortgage is repaid once the borrowers move, sell, or pass away (in which case the heirs owe the lesser of the balance and the home value). The lender may not require immediate payment in full if a non-borrowing spouse is occupying the home.

If the borrowers sell the home, for example to move away, they keep proceeds in excess of the mortgage balance.

## Loan Purpose

By “loan purpose” we simply mean “the thing the borrower is going to do with the loan”. For mortgage loans, 12 C.F.R. §1026.37 (a)(9) requires that the loan estimate use one of the following purposes:

- Purchase
- Refinance
- Construction
- Home Equity Loan

The relevant MISMO data points for first mortgages are `LoanPurposeType` with values `Purchase` and `Refinance` and (for refs) `RefinanceCashOutDeterminationType` with values `NoCashOut`, `LimitedCashOut`, and `CashOut`.

By “purchase” we mean that the loan is for the borrowers to purchase the residence, whereas by “refinance” we mean that the borrowers are replacing some existing loan(s) on their already-owned property with a new loan. Here the edge case is a transaction where (for example because of a divorce settlement) one owner is required to buy out the interest of another owner: this would generally be considered a refi.

A “cash-out” refi indicates that the borrowers are, at closing, to receive some significant amount of money—guidelines vary over time and by lender, but for instance in 2026 the Fannie Mae guideline puts the threshold at the greater of 1% of the loan amount or \$2,000.

HELOCs and reverse mortgages have different purposes.

As we saw above, construction loans may or may not be considered a distinct loan purpose. What do we mean by “construction loan” exactly? Both the financing of construction of brand new premises and renovations of existing premises are typically thought of as “construction loans”. The distinguishing feature of construction loans is that not all of the financing is for purchasing the land or paying off existing loans: at least *some* of the financing is paying for construction/renovation.

There are multiple possible construction loan arrangements, and this gets more into custom lending situations, but the most typical are probably:

- automatic conversion (i.e., to permanent)
- modification agreement
- one-time close
- two closings
- via a new note

Whatever the path, the end result of construction lending is typically some permanent financing that would simply be considered a purchase or refi.

An example construction loan arrangement is a construction to permanent with a one-time close where, by way of just one loan closing, the lender makes disbursements of principal during construction (per a construction contract, for example via “progress payments” as construction progresses) and where on the day construction ends the loan becomes the “permanent mortgage loan”. Here the definition of “owner occupied” (see [Occupancy](#)) is relaxed so that the clock starts the day of the last disbursement, typically 60 days after the last disbursement.

Of these different loan purposes, a refi is in some sense the simplest to originate as the borrower already owns the [collateral](#).

## Collateral

The collateral for a home loan is some kind of residence—excluding commercial sorts of residences such as hotels—owned by the borrower with good and marketable title that may be held or conveyed freely and is suitable for collateral.

## Property Types

The collateral must be some kind of residence. Property types for a home loan include:

- Single Family Residence (SFR)
  - Possibly in a Planned Unit Development (PUD)
  - Possibly with an Accessory Dwelling Unit (ADU)
- Condominium Units (“Condos”)
  - Could be attached or detached
- Cooperative Housing (“co-op”)
  - Could be attached or detached

- Manufactured Homes
  - Possibly in a PUD
  - Possibly in a Condo Project
- 2-4 Unit Property
  - Including 2-3 Unit with an ADU

What are the edge cases?

A line between residential and commercial has to be drawn somewhere: 2-4 units is fine, but 5 or more units—for example a loan for a 5-unit apartment complex—crosses into commercial purposes as far as home loans are concerned (yes, an apartment may still be classified as residential property for purposes of depreciation or other tax purposes).

The other edge: a rural property with a home and a few acres of farmland might still be in scope for a home loan to the extent that the highest and best use is residential, whereas a loan for some large piece of farmland that also happens to have a farmhouse would not be a home loan.

Similarly, a loan for raw land is not a home loan, and while a lot loan (i.e., unimproved land already zoned for housing with access, utilities, and so forth) may not be thought of as a home loan on its own, it likely *would* be considered a home loan in the case of a construction loan arrangement that included the purchase of the unimproved land (or leasehold interest) and construction costs for the site-built home (or installation of the manufactured home).

Some lenders may offer loans on more “exotic” types of residences. For instance, as of 2026 the Freddie Mac Seller/Servicer Guide lists a few non-traditional property types that are nonetheless potentially eligible for delivery:

Mortgages secured by non-traditional types of properties are eligible for delivery to Freddie Mac. Examples of non-traditional or unique property types include, but are not limited to:

- “Barndominiums” (barn conversions or barn-style buildings)
- “Shouses” (living-space and work/storage combinations)
- Berm homes
- Log homes
- Geodesic dome dwellings

A comment on manufactured homes: manufactured homes are stationary collateral and not to be confused with mobile homes. One clue is manufactured homes have a HUD Certification Label (a metal plate) attached on the exterior of each transportable section. Another clue is that manufactured homes will not have wheels, axles, or towing hitches. Manufactured homes may be suitable collateral for a home loan, whereas the other thing with wheels and axles is not suitable. Manufactured homes are also distinct from the sorts of factory-built modular housing that are assembled on site (manufactured homes are only modular to the extent they can be single-wide, double-wide, etc.). For collateral purposes, factory-built modular homes assembled on site are essentially the same as site-built homes assembled on site, and both are regulated by the same sorts of local building codes (as opposed to HUD-regulated manufactured homes).

It’s worth clarifying that although in many contexts “property” includes the land and the improvements, in some contexts we mean just the residential building. For example, the determination whether or not flood insurance is needed would look at whether the residential building is in the flood zone, not whether any piece of the land is in the flood zone. Note though that not every home loan involves collateral where the borrower owns the underlying land; this brings us to the topic of property ownership interest.

## Property Ownership Interest

There are many senses in which the borrower can own the collateral, so for home loans purposes it’s useful to break it down into three components, the first of which is ownership interest. The borrower’s ownership interest in the property may be:

- fee simple estate
- leasehold estate (the improvements are owned, the land is leased)
- cooperative interest (ownership of shares in the co-op with a lease)

Technically, borrowers owning a property fee simple or leasehold own an “estate” in land, hence the terminology. The fundamental idea is that ownership can be divided. Quoting Stephen Leake in *An elementary digest of the law of property in land* (1909):

By reason of the perpetuity and uniform continuity of estates the use of Land the future use may be considered separately from the present possession, and may be limited or measured out by intervals of time and treated in distinct property or properties

We can separate present possession from future use, and to quote Herbert Tiffany in *The law of real property and other interests in land* (1912):

The most distinctive feature of the law of land as established in England, and from there brought to this country, is the doctrine of estates, by which the rights of possession and enjoyment are rendered capable of division according to time.

...

The future possession and use of the land is accordingly the subject of present ownership, and, consequently, of present transfer, apart from its present possession and use. The owner of land, or, more properly speaking, of an “estate” in land, may therefore, by an act of transfer, determine the person or persons who shall enjoy the land in the future, as well as in the present, creating, at his pleasure, interests or “estates” in various persons, to begin or end as he may declare at the time of the transfer; his power in this respect being limited, generally speaking, only by his inability to create any estate which will extend beyond the limits of his own estate.

Upshot from a lending perspective is there’s no one single sense in which a property is owned.

Fee simple ownership is the most common ownership interest in residential mortgage lending. The borrower with a fee simple estate owns both the land and the improvements, subject to any liens, easements, deed restrictions, or governmental regulations affecting the property. This is the “highest” level of private ownership of land. As Thomas Littleton put it in the 15th century:

Tenant en fee simple is he whiche hath landes or tenementes to holde to hym and to his heyres for euer.

Leasehold ownership in contrast is not perpetual and does not cover the underlying land. Lenders will generally require that the term of the leasehold estate runs beyond the maturity date of the home loan. For example, under Freddie Mac guidelines (as of 2026) the lease must run for at least five years beyond the loan maturity date.

Co-ops are the least common form of ownership interest nationally, for the most part being specific to just a few areas, mostly New York City (but with pockets elsewhere). While fee simple and leasehold are estates in land, co-op ownership is via ownership of shares in the co-op. The cooperative housing association has title to the land and the tenant-stockholders own the co-op. Per 26 U.S.C. §216, defining a cooperative housing corporation:

... each of the stockholders of which is entitled, solely by reason of his ownership of stock in the corporation, to occupy for dwelling purposes a house, or an apartment in a building, owned or leased by such corporation, ...

A condominium is generally *not* a separate ownership-interest category. A condominium owner typically holds title to the unit (fee simple or leasehold) together with an undivided interest in the common elements of the condominium project.

Some lenders include life estates as separate category and lend to borrowers possessing the collateral in this way. As described in *The law of real property and other interests in land* by Herbert Tiffany:

An estate for life is a freehold interest in land, the duration of which cannot extend beyond the life or lives of some particular person or persons, but which may possibly endure for the period of such life or lives.

The equivalent MISMO data point name is `PropertyEstateType` with values `FeeSimple`, `Leasehold`, and (just added in 2026) `Other`.

As an example property ownership interest scenario, a borrower might have a SFR property held as a fee simple estate: they own the land and the improvements on that land, including the single residential unit and possibly an ADU. But *how* do they own that property exactly? The answer is it depends on the property ownership vehicle.

## Property Ownership Vehicle

The property ownership vehicle is *how* the borrower owns the property. Ownership may be held directly by the borrower or through a legal ownership vehicle such as a land trust, inter vivos revocable trust, etc. If a land trust holds legal title, then the borrower must be a beneficiary of the trust.

The vehicle used may affect loan eligibility; for example, a given lender might not permit ownership via an LLC or certain types of trusts. Lending requirements concerning who needs to sign which documents also follow from the ownership vehicle.

The most common vehicles are to either simply hold the property directly or to own it via a revocable family trust (where at least one individual establishing the trust is a borrower). This still leaves open the question as to the form of ownership taken, i.e., how title is vested.

## Title Vesting

There are many ways the borrowers can hold title to the collateral. Common title vesting choices include:

- sole ownership
- joint tenancy
- tenancy in common
- tenancy by the entirety
- community property (community property states)
- community property with right of survivorship (community property states)

As an example of sole ownership, if a married borrower wanted to take title separately from her spouse, she might take title as “OLIVIA OBLIGOR AS HER SOLE AND SEPARATE PROPERTY”. Or for co-ownership, a security instrument (see [Lien](#)) might list the borrower as “BEN BORROWER AND ANNA APPLICANT, HUSBAND AND WIFE AS COMMUNITY PROPERTY WITH RIGHT OF SURVIVORSHIP”.

All together there are many variations of the ownership interest, vehicle, and manner of vesting title, but from the lender’s perspective, the outcome just needs to be such that it’s suitable as collateral. But how exactly does the lender force a sale of the property in the event of a default? The answer is via a lien on the property.

## Lien

The lender enforces their lien via a security instrument specifying the collateral. Along with the promissory note, the security instrument is one of the two core loan documents signed by the borrowers. Example security instrument language:

This Security Instrument secures to Lender (i) the repayment of the Loan, and all renewals, extensions, and modifications of the Note, and (ii) the performance of Borrower’s covenants and agreements under this Security Instrument and the Note. For this purpose, Borrower mortgages, grants, and conveys to Lender, the following

described property located in the [Type of Recording Jurisdiction] of [Name of Recording Jurisdiction]: which currently has the address of \_\_\_\_\_ (“Property Address”);

The security instrument could be a mortgage, deed of trust, or security deed.

### **Mortgages (Mortgagor and Mortgagee)**

A mortgage has the borrower in the role of mortgagor and the lender in the role of mortgagee. Example mortgage language:

Parties (A) “Borrower” is \_\_\_\_\_, currently residing at \_\_\_\_\_. Borrower is the mortgagor under this Security Instrument. (B) “Lender” is \_\_\_\_\_. Lender is a \_\_\_\_ organized and existing under the laws of \_\_\_\_\_. Lender’s address is \_\_\_\_\_. Lender is the mortgagee under this Security Instrument. The term “Lender” includes any successors and assigns of Lender.

### **Deeds of Trust (Trustor, Beneficiary, and Trustee)**

A deed of trust has an additional party: deeds of trust put the borrower in the role of the trustor, the lender as the beneficiary, and a third party as the trustee. Example deed of trust language:

Parties (A) “Borrower” is \_\_\_\_\_, currently residing at \_\_\_\_\_. Borrower is the trustor under this Security Instrument. (B) “Lender” is \_\_\_\_\_. Lender is a \_\_\_\_ organized and existing under the laws of \_\_\_\_\_. Lender’s address is \_\_\_\_\_. Lender is the beneficiary under this Security Instrument. The term “Lender” includes any successors and assigns of Lender. (C) “Trustee” is \_\_\_\_\_. Trustee’s address is \_\_\_\_\_. The term “Trustee” includes any substitute/successor Trustee.

### **Enforcing the Lien**

Under a mortgage, if the mortgagor defaults, the mortgagee needs to take the mortgagor to court (foreclosure process), whereas with a deed of trust we have the remedy baked into the security instrument:

Notice of Sale; Sale of Property. If Lender invokes the power of sale, Lender will execute or cause Trustee to execute a written notice of the occurrence of an event of Default and of Lender’s election to cause the Property to be sold. Trustee will cause this notice to be recorded in each county in which any part of the Property is located. Lender or Trustee will mail copies of the notice as prescribed by Applicable Law to Borrower and to the other required recipients. Trustee will give public notice of sale to the persons and in the manner prescribed by Applicable Law. At a time permitted by, and in accordance with Applicable Law, Trustee, without further demand on Borrower, will sell the Property at public auction to the highest bidder at the time and place and under the terms designated in the notice of sale in one or more parcels and in any order Trustee determines.

Thus, all else being equal, it can be less expensive to enforce a lien using the power of sale under a deed of trust than under a mortgage. Every state allows judicial foreclosures, but only some states permit a power of sale foreclosure without a lawsuit, and in practice, lenders tend to classify states as either judicial (mortgage) state, non-judicial (deed of trust) states, or hybrid states.

### **Security Deed (Grantor and Grantee)**

The third type of security instrument is the security deed (for subject properties in Georgia). Under the security deed the borrower is in the role of grantor, the lender as grantee.

Parties (A) “Borrower” is \_\_\_\_\_, currently residing at \_\_\_\_\_. Borrower is the grantor under this Security Instrument. (B) “Lender” is \_\_\_\_\_. Lender is a \_\_\_\_ organized and existing under the laws of \_\_\_\_\_.

\_\_\_\_\_. Lender's address is \_\_\_\_\_. Lender is the grantee under this Security Instrument. The term "Lender" includes any successors and assigns of Lender.

Security deeds, like deeds of trust, have the remedy already agreed to in the security instrument:

If the Default is not cured on or before the date specified in the notice, Lender may require immediate payment in full of all sums secured by this Security Instrument without further demand and may invoke the power of sale granted by Borrower and any other remedies permitted by Applicable Law. Borrower appoints Lender the agent and attorney-in-fact for Borrower to exercise the power of sale.

## Lien Position

Loans in the first lien position are referred to as "first lien". Subordinate liens are "second lien" (occasionally "third lien"). Subordination may be necessary to reorganize the priority of any existing liens on the collateral.

## Homesteads

One other detail concerns homesteads. States may have protections for "homesteads", meaning the primary residence, though these protections generally operate against judgment creditors and other claimants rather than against the mortgagee/beneficiary. For example, per the California constitution Article XX §1.5 (and this goes back to the original 1849 adoption):

The Legislature shall protect, by law, from forced sale a certain portion of the homestead and other property of all heads of families.

The "certain portion of the homestead" is defined under the California Code of Civil Procedure §704.730.

The amount of the homestead exemption is the greater of the following:  
(1) The countywide median sale price ... not to exceed six hundred thousand dollars.  
(2) Three hundred thousand dollars.

Those amounts are from 2021 and adjust annually with inflation, and as of 2026 this puts the ceiling at \$743,459 and the floor at \$371,547. Significant amounts, but again, not applicable to a home loan lender enforcing a valid consensual lien. It does matter for *judgment* creditors per §704.950(c):

A judgment lien attaches to a declared homestead in the amount of any surplus over the total of the following:  
(1) All liens and encumbrances on the declared homestead ...  
(2) The homestead exemption

Where homestead laws *do* come into play is Texas. Texas homestead law is significant in that it shapes the terms of certain home loans to the extent that "Texas a6 loans"—referring to the Texas constitution article 16 §50 (a)(6)—get called out as a separate category by industry participants. Critically, an 80% **CLTV** rule applicable to cash-out refis and **CESs/HELOCs** (but not purchases) is baked into the Texas homestead protection:

The homestead of a family, or of a single adult person, shall be, and is hereby protected from forced sale, for the payment of all debts except for ... an extension of credit that ... is of a principal amount that when added to the aggregate total of the outstanding principal balances of all other indebtedness secured by valid encumbrances of record against the homestead does not exceed 80 percent of the fair market value of the homestead on the date the extension of credit is made...

The Texas laws introduce other complexities as well, of which this 80% CLTV clause in article 16 §50 (a)(6)(B) is just the (arguably) most significant. But what do we mean by "80% CLTV" here? This gets into the topic of collateral value and LTV.

## Collateral Value and LTV

Collateral value is generally determined via an appraisal. The most robust (“full”) interior & exterior appraisals are:

- 1004 (Uniform Residential Appraisal Report)
  - 1-unit properties with or without an ADU
  - PUD units
  - detached condo units
- 1004C for manufactured homes
  - including those in a PUD, condo, or co-op
- 1025 for 2-4 units
  - including those in a PUD, condo, or co-op
- 1073 for condo units
- 2090 for co-op units

The 1004, 1004C, etc., above refer to the names of the standardized forms that originated with the GSEs. The forms and their names are industry standard even for Nonconforming loans.

A “drive-by” appraisal is one where the appraiser does visit the location but does not inspect the interior, for example just to update a prior appraisal.

A “desktop” appraisal is when the appraiser uses third-party data (public records, third-party inspections, photos from third parties) and does not visit the location.

Automated Valuation Models (AVMs) come up with home value estimates. A lender may waive an appraisal based on AVM estimates.

Appraisals and AVM estimates are both estimates of the market value. Generally the collateral value uses the most recent appraisal, that being the most up-to-date estimate. For a purchase transaction we have an actual sales price, so the collateral value is the lesser of the actual sales price from the purchase contract and the appraisal amount from the appraisal report (there’s no way to obtain a larger loan simply because the appraisal came in higher than the sales price).

The loan amount together with the collateral value yield the Loan-to-Value (LTV) ratio, typically multiplied by 100 to put in units of percent, e.g., “80% LTV”.

### LTV Types

There are many variations of origination LTV in the industry and multiple naming conventions. What all have in common is the denominator (the “V”) will be some collateral valuation and the numerator will be some combination of:

- the base loan amount less any financed MI or VA funding fee
- the financed MI premium of VA funding fee
- HELOC and CES balances
- unused HELOC line available to draw

Thus there are five possible components to the origination LTV ratios (Figure 6).

B	Base Loan Amount
F	Financed MI
D	HELOC Draws + CES Balances
U	Undrawn Available HELOC Line
V	Collateral Value

Figure 6: Components of Origination LTV

Each type of LTV is some ratio  $\Lambda$  of some amount borrowed against the collateral over the collateral value (Figure 7).

$$\frac{\boxed{?}}{\boxed{V}} \quad \text{Ratio } \Lambda \text{ of amount borrowed against collateral to collateral value } \boxed{V}$$

Figure 7: Structure of a Loan-to-Value (LTV) ratio

There are six varieties of origination LTV commonly used in the industry. What differs between origination LTV types is the numerator. Every market participant uses *some* of these. The Uniform Loan Delivery Dataset (ULDD) used by both Freddie and Fannie includes four of the six types of origination LTV. There is no universally recognized naming convention, but we can label them  $\Lambda_1 \dots \Lambda_6$  (Table 1) then go through the components of each one.

Ratio	Description	Base Loan	Financed MI	Draws + Balances	Unused Line
$\Lambda_1$	Base LTV	✓			
$\Lambda_2$	LTV	✓	✓		
$\Lambda_3$	Base CLTV	✓		✓	
$\Lambda_4$	CLTV	✓	✓	✓	
$\Lambda_5$	Base HCLTV	✓		✓	✓
$\Lambda_6$	HCLTV	✓	✓	✓	✓

Table 1: Components of the numerators for different Origination LTV ratios

**Base LTV** The smallest ratio is what the GSEs name as `BaseLTVRatioPercent` in the ULDD standard (Figure 8). With this base LTV we consider just the original loan amount less any financed MI, FHA MIP, or VA funding fee. Primary market players—HUD, VA, most private MI companies—generally just call this LTV, though MGIC does call it out as Base LTV, FHA clarifies that unless stated otherwise “LTV” means base loan amount in the numerator, and Essent occasionally uses “net LTV” for clarity.



Figure 8: Base LTV

This base LTV is the LTV that determines where MI will be required.

**LTV** What the GSEs designate as `LTVRatioPercent` in the ULDD standard includes the total loan amount, i.e., the base loan amount including any financed MI (Figure 9). Primary market participants often do not have a data point for this combination.



Figure 9: LTV

This LTV reflects the full amount financed from the first lien, i.e., what is often called the total loan amount. It's more relevant for a market participant more concerned about the accounting perspective: how much is actually on the books, what's the actual original unpaid principal amount (which ties with actual monthly payment amounts), etc.

It can be ambiguous whether someone is using “LTV” to refer to this type (`LTVRatioPercent`) or to `BaseLTVRatioPercent`. The results are identical if there is no financed MI.

**Base CLTV** MGIC includes this data point, naming it CLTV. We might name it Base CLTV to keep naming distinct (Figure 10).



Figure 10: Base CLTV

This ratio reflects total secured debt while excluding financed MI.

**CLTV** This is what the GSEs designate as `CombinedLTVRatioPercent` in the ULDD standard: total loan amount plus HELOC & CES balances divided by the collateral valuation amount (Figure 11). Fannie and Ginnie name this CLTV whereas Freddie calls it TLTV. Primary market participants often do not have a data point for this combination while at the same time may have something else called CLTV, potentially leading to confusion.



Figure 11: CLTV

**Base HCLTV** Primary market players sometimes have a ratio that uses base loan amount plus balances and undrawn available line in the numerator (Figure 12). For example, MGIC has this combination under the name HTCLTV.

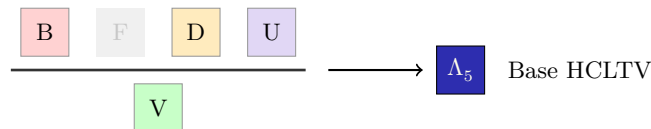


Figure 12: Base HCLTV

**HCLTV** The GSEs call this HomeEquityCombinedLTVRatioPercent in the ULDD standard (Figure 13). Fannie calls this HCLTV while Freddie refers to it as HTLTV. Primary market participants often do not have a data point for this combination.

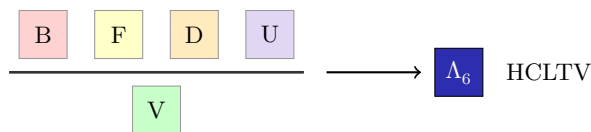


Figure 13: HCLTV

What should we count here in the event of a frozen HELOC line? Generally, if the HELOC line is *temporarily* frozen then we would use the full line, whereas if it is *permanently* frozen we use the balance. Likewise, a HELOC in the repayment period has no available line, so we use the balance. When the balance exceeds the line then by how we’ve defined it here the *unused available* line is zero—we could have also defined this quantity as “the greater of the balance and the available line”.

If there’s a theme it’s that the primary market tends to favor base loan amount as this is most applicable to the decision to extend credit whereas the secondary market tends to favor total loan amount as being more relevant to what’s actually on the books. Moreover, on the secondary market there’s the need to get “current” versions of LTV, CLTV, and HCLTV using current unpaid principal balance and in some cases refreshed collateral valuations. Having distinct HELOC balance vs. HELOC full line variations are helpful for [prepayment modeling](#).

We see that some LTV types are distinguished by whether or not financed MI is included. So what is MI exactly?

## Mortgage Insurance

Mortgage insurance (MI) transfers a portion of the credit risk from the lender to the insurer. Specifically, MI protects the lender in the event of borrower default. How much protection? MI plans have a coverage percent: this is the percentage of the original loan amount that the mortgage insurer agrees to reimburse the lender for covered losses in the event of borrower default. The home loan already involves collateral, so the

lender is not expecting 100% coverage through the MI; example real-life MI coverage levels would be 12%, 18%, 25%, 30%, 35%. The coverage percentage does not cap losses at that amount; rather, it determines the maximum claim payable by the insurer under the terms of the policy.

The requirement is not universal, but lenders generally require mortgage insurance (MI) for loans having a higher LTV, usually higher than 80%. For most loans for states other than New York, MI is typically required if the LTV exceeds 80%, whereas in New York state, excepting only refis and co-op purchases which follow the standard LTV rule, MI is generally required if the ratio of the loan amount to the appraised amount exceeds 80% (i.e., sales price does not enter into the picture). An example of how this 80% limit is not universal: lender special programs for loans they intend to hold in portfolio may not require MI even above 80% LTV.

If the loan is insured by the federal government, then the loan is referred to as government insured, the most common being FHA and VA. If the loan is instead insured via private mortgage insurance, the loan is referred to as conventionally insured (“conventional”). The conventional label is commonly used to describe uninsured as well.

## Conventional

A conventional loan is any home loan that is not insured by a federal agency. Conventional loans may be:

- uninsured
- conventionally insured using private mortgage insurance

Example private insurers: Essent, MGIC, Radian.

If it's insurance then we must have a premium, but how is that set up? There are different MI premium payment arrangements:

- borrower-paid (BPMI)
  - monthly premium
  - single up-front premium
    - \* borrower may get a partial refund if MI cancels significantly early
    - \* could be financed in whole or in part
    - \* could have help from lender credits or a third party (e.g., builder)
  - split premiums (hybrid up-front + monthly)
- lender-paid (LPMI)
  - single premium paid at time of insurance activation
  - baked into a higher interest rate or partly covered by higher origination fee

BPMI may be cancelled once LTV drops to 80% and should be cancelled automatically (per the Homeowners Protection Act of 1998) once LTV (based on original property value) drops to 78% through normal scheduled amortization or reaches the midpoint of the amortization period (assuming borrower is still current on payments).

Private MI is easy enough to cancel once it is no longer required. FHA uses mortgage insurance premiums (MIP), which follow different cancellation rules.

Conforming conventional home loans may be delivered to **Fannie Mae** or **Freddie Mac**.

## FHA

The Federal Housing Administration (FHA) is part of the Department of Housing and Urban Development (HUD), so some FHA-related topics will have “HUD” in the name, for instance HUD 4155.1 Mortgage Credit Analysis for Mortgage Insurance or HUD 4000.1 Single Family Housing Policy Handbook.

The FHA mortgage insurance premium is referred to as the MIP (Mortgage Insurance Premium), and when financed into the loan amount as the UFMIP (Up Front Mortgage Insurance Premium).

The National Housing Act of 1934 established the FHA, so FHA programs are often referred to using the relevant sections of that act, though today you would look up the law under 12 U.S.C. §1709. For example, “203(b)” programs are named after part b of section 203, the language of which part starts with:

(b) To be eligible for insurance under this section a mortgage shall comply with the following

Similarly, 203(h) loans for disaster victims is named after section 203 part h:

(h) Notwithstanding any other provision of this section, the Secretary is authorized to insure any mortgage which ... was destroyed or damaged to such an extent that reconstruction is required as a result of a flood, fire, hurricane, earthquake, storm, or other catastrophe, which the President ... has determined to be a major disaster.

Relevant sections include:

- 203(b) Basic FHA-insured Home Loan
- 203(h) Disaster Victims
- 203(k) Rehabilitation
- 247 Hawaiian Home Lands
- 248 Mortgages on Indian Land
- 251 ARMs (ended up with their own section)

Sections are not always cited, for example section 234(c), which authorizes loans for condo units but may not be used to describe the loans as such:

(c) The Secretary is authorized ... to insure any mortgage covering a one-family unit in a multifamily project and an undivided interest in the common areas and facilities which serve the project if (1) the mortgage meets the requirements of this subsection and of section 203(b), except as that section is modified by this subsection ...

Types of FHA loans include:

- Refinances for existing FHA loans
- Purchases
- New Construction
- Construction to Permanent
- Building on Own Land
- Energy Efficient Mortgage (EEM)
- Weatherization (may combine with EEM)
- Solar and Wind Technologies
- Assumptions (i.e., transfer to assuming borrower)
- HUD REOs (Real Estate Owned)

FHA-insured home loans are typically delivered to **Ginnie Mae** and may also be acquired by **Fannie Mae** or **Freddie Mac**.

Not every loan is FHA-eligible. FHA limits the maximum loan amount, thus in theory focusing support on low and moderate-income borrowers and moderately-priced housing rather than higher-priced luxury homes.

FHA loan limits are the lesser of the nationwide mortgage limit for the area and a percentage of “adjusted value” (lesser of the property value and the purchase price less inducements). As of June 2026, the highest limit is \$3,490,300 which is for a 4-unit property in AK/HI/GU/VI. For other states/territories the maximum possible is \$2,326,875 for a 4-unit in a high cost MSA.

The federal government also offers more narrowly-scoped insurance programs: VA, USDA Rural Development, and Section 184s.

## **VA, USDA, Section 184s**

Veterans Administration (VA) guarantees home loans for servicemembers, veterans, and some surviving spouses. Although technically a guaranty as opposed to insurance, common usage is still to refer to these as “government-insured”.

An example VA loan program is the VA Interest Rate Reduction Refinance Loan, VA IRRRL (“Vee Ay Earl”). VA IRRRLs are a streamline refi.

Section 184 refers to the Indian Housing Loan Guarantee Program. Section 184 guarantees cover American Indian and Alaska Native, whereas Section 184A is for the Native Hawaiian Housing Loan Guarantee. The Office of Public and Indian Housing (PIH) oversees the programs with the guarantee coming from the Office of Loan Guarantee under the Office of Native American Programs (ONAP). Just as with FHA there are loan limits: as of 2026 the largest possible Section 184 is \$2,326,875 for a 4-unit property (multiple high-cost counties) and largest possible Section 184A is \$2,136,400 (Kauai).

Section 502 refers to Rural Housing Service (RHS) loans authorized by section 502 of the Housing Act of 1949 (42 U.S.C. 1472). Sometimes referred to as “RD” (Rural Development). RHS is part of the USDA (United States Department of Agriculture). As of 2026, the largest possible loan is \$779,700 (Maui and Molokai). The loans have an upper income limit as well. These are for rural areas only, so for example most of Orange County California is not eligible (though if you’re in an eligible area of Orange County, the largest possible loan is \$749,400 and the income limit for a 4-person household is \$194,550).

VA-insured home loans and Section 184s & 502s may be delivered to **Fannie Mae**, **Freddie Mac**, or **Ginnie Mae**.

## **Occupancy**

Occupancy is one of the primary underwriting dimensions as experience has shown it to be relevant to credit risk: borrowers are more likely to continue making payments on their primary residence than on a second home or investment property.

Owner occupied (OO) is generally defined as when borrowers occupy the subject property (if a refi) or *intend* to occupy the subject property in the 60 days after closing (for a purchase). This is also referred to as Primary Residence (PR) or Principal Residence.

Non-owner-occupied (non-OO) deals have two variants. When borrowers intend to occupy the subject property only occasionally, this is a second home. Alternatively, investment property means the borrowers intend to rent or lease out the subject property, i.e., as an income-generating investment.

The MISMO data point name is `PropertyUsageType` with values `PrimaryResidence`, `SecondHome`, and `Investment`.

For an OO scenario, the monthly housing expense (MHE) and the subject property PITIA are one and the same. Otherwise, if the borrowers do not intend to occupy the subject property, their MHE and PITIA are not one in the same, in which case MHE is the PITIA of their occupied residence, or their rent if they are renting, or potentially zero if their home is owned free and clear.

Misrepresentation of occupancy is a type of mortgage fraud.

Occupancy Type	Borrower Lives There?	Rental Income Expected?
Owner-Occupied / Primary Residence	Yes (majority of the year)	Usually No
Second Home / Vacation Home	Occasionally / Seasonally	No
Investment Property	No	Usually Yes

Table 2: Subject Property Occupancy Types

## Secondary Market

The lender may plan to retain a loan in their portfolio, in which case they will designate it as HFI (held for investment). They may also intend to sell a loan, in which case it will be designated as HFS (held for sale). In what market are these loans sold?

In the context of home loans, “secondary market” refers to the market where the notes and servicing rights are traded after origination. This provides liquidity to lenders, i.e., money for papers for money. A few highlights:

- GNMA created the very first **MBS** in 1970.
- The TBA (To-Be-Announced) market followed.
  - Sell forward
  - Trade date: terms are agreed upon
    - \* issuer, i.e., **FNMA**, **FHLMC**, **GNMA**
    - \* maturity
    - \* coupon
    - \* face value
    - \* price
    - \* settlement date
  - Notification date (two days before settlement): specifics are set
  - Settlement: money for pools
- Specified pools
  - Specifics are set earlier at the time of the trade
- FHLMC issued the first **CMO** in 1983.

Agency securities are backed by GNMA, FNMA, or FHLMC. Otherwise, the security is non-agency.

The selling and pricing of home loans is commonly the responsibility of the lender’s secondary marketing department. The *OCC Comptroller’s Handbook* chapter on mortgage banking (2014) has a good description (this is for banks but still works for non-bank lenders):

Many banks engaged in mortgage banking activities originate loans and sell them into the secondary market.

A bank’s secondary marketing department, working with production management, should be responsible for

- developing new products.
- pricing mortgage loans.
- managing and hedging the pipeline and warehouse.
- selling mortgage loans and effecting best execution.
- contributing to mortgage banking profitability.
- documenting and delivering mortgage products to investors.
- managing repurchases, indemnifications, and recourse obligations.

The market is not exclusively for home loans—technically, a small portion is made up of Commercial MBS (CMBS), i.e., a bond collateralized by commercial or 5+ unit. Looking at the big picture, for total MBS (i.e., agency MBS, agency **CMO**, non-agency CMBS, non-agency RMBS) in 2026Q1 we see:

- issuance was \$541B
  - 69% agency MBS
  - 25% agency CMO
  - remaining 6% split 73/27 between CMBS and RMBS
- the average daily trading volume was \$415B
  - behind US treasuries (\$1.2T)
  - ahead of corporates (\$71B)

By “RMBS” above we mean non-agency residential MBS (RMBS), so just the CMBS part (73% of the 6%) is commercial.

HELOCs may be sold into ABSs (Asset-Backed Securities). ABSs will be rated by one or more ratings agencies (the big three nationally-recognized statistical ratings organizations are Moody’s, S&P, and Fitch). ABS deals may have many classes (by structuring tranches at different senior/subordinate levels). Auto loans and student loans are other types of ABS collateral.

The credit risk follows from the possibility that borrowers default on their home loans and that the proceeds of the sale of the collateral fall short of the unpaid balance. One approach to mitigating this credit risk is by pooling multiple home loans into an **MBS** or other security backed by one of the agencies.

## MBS

A Mortgage Backed Security (MBS) is a pass-through built on a pool of multiple home loans. From the weighted average note rate we subtract a g-fee (guarantee fee) and servicing (including excess servicing) with optional buy-up or buy-down to dial in a pass-through coupon rate.

The CUSIP uniquely identifies the MBS (or other North American security). CUSIP is pronounced “Q-sip”. It’s an acronym for Committee on Uniform Security Identification Procedures. This is not the same as the pool ID. The clue: CUSIPs are nine alphanumeric characters long.

Many MBS attributes start with “WA” as in Weighted Average, e.g., WAC for Weighted Average Coupon.

The MBS approach greatly reduces credit risk. However, the duration of an MBS is not known with certainty as the maturities of the underlying home loans is uncertain (see **Prepayment**), so we still have funding and reinvestment risk: investors will tend to receive principal earlier when interest rates drops and later when they increase.

A basic unstructured MBS is a pass-through. Collateralized mortgage obligations (**CMOs**) are structures created from MBSs that can restructure risks and cash flows into more desirable deals.

## CMO

CMOs are securitization structures that redistribute the cash flows from mortgage collateral among two or more tranches. This multi-class structure is the defining feature of CMO, whereas MBS, UMBS, Supers, etc., are all single-class securities. The process of splitting MBS or ABS cash flows into different tranches is called structuring, and the structure that maximizes the proceeds from securitization is the “best execution” (this is for MBS and CMOs). The resulting increase in proceeds is the “arbitrage” (or just “the arb”), though to be clear this is not riskless arbitrage in the textbook sense.

CMOs date back to June 1983 with the current REMIC (real estate mortgage investment conduit) tax designation showing up a few years later. The terms are used interchangeably, though technically REMIC refers to the tax structure. Freddie Mac MACRs receive their payments from related REMICs (MACR refers to a modifiable and combinable REMIC). Fannie Mae RCR certificates (combinable and recombinable

certificates) likewise may combine payments from related REMICs. REMICs are commonly originated as a trust but may be a partnership or other entity.

As an example, Fannie Mae REMIC Trust 2026-42 (from May 2026) sets up 21 classes, 20 of which are divided into seven groups. Each class has its own CUSIP. Thus, we can look up a given class using the corresponding CUSIP or all the classes at once via the trust ID. In this example, Fannie Mae issues the classes and guarantees that required payments of principal and interest on the certificates are available for distribution to investors on time.

Agency CMOs such as the previous example are made of agency pass-throughs, whereas non-agency (aka private label) CMOs are backed by loans that are not in agency pass-throughs.

CMOs do not trade on a TBA basis.

There are multiple dimensions on which to structure a deal, keeping in mind that a CMO is a closed universe, e.g., the existence of a senior tranche implies we also have a subordinate tranche. Possibilities include:

- credit structuring
  - subordination
  - overcollateralization
  - excess spread (i.e., interest earned - interest due)
- cash flow structuring
  - time / sequential tranching
  - PACs (planned amortization classes) with PAC band + support
  - TACs (targeted amortization classes)
  - Z-bond / accretion direction
  - IOs + POs
  - floater + inverse

An example structure—this is not specific to home loans—is the “six-pack”: a senior AAA tranche in the very last loss position, then AA, A, BBB, BB, and B, plus an unrated first loss piece. Losses are absorbed from the bottom up.

The oldest flavor of CMO structuring is time / sequential tranching (which dates back to June 1983) where the sequential means principal is paid into one class first then each subsequent class in sequence, resulting in the classes maturing in sequence. Sequential tranching and Z-bonds are related concepts. Z-bonds (“Zs”) are tranches where the bond coupon accrues by adding interest to the principal. These are also called accrual bonds. Going back to the original 1980s deals, mortgage cash flows in a CMO might be divided into four sequential pay tranches labeled A, B, C, and Z: the first principal payments go to Tranche A—which reaches maturity first—then Tranche B gets the second principal payments, etc., with Tranche Z being the last to receive principal payments (see [Prepayment](#)).

PACs go beyond sequential tranching by creating cash flows that are protected from prepayments within predefined limits, creating at least two bands: the PAC tranche and the support. TACs on the other hand offer protection from faster than expected prepayments but not extension risk.

In general, structures that address prepayment risk are more relevant to agency CMOs (the agency having already guaranteed required payments are made on time) whereas structures that address credit risk are more relevant for non-agency CMOs.

Bottom line: structuring ideally yields a “sum of the parts is greater than the whole” outcome vis-à-vis the cash flows of a pass-through MBS. MBSs have another component, though: the mortgage servicing rights (MSRs).

## MSRs and Servicing

Mortgage servicing is an operational role: servicers need to collect monthly payments, remit principal and interest to the investors, manage escrow accounts, handle delinquencies and foreclosures, and take care of investor reporting. Somehow the servicer needs to be compensated for doing this work. The primary mechanism for doing so is the servicing fee.

The servicing fee is baked into the MBS coupon. The servicer earns a servicing strip each month loans remain outstanding. This leads us to Mortgage servicing rights (MSRs) which can be bought and sold separately from the ownership of the MBS. MSRs have a value, more or less, of the discounted present value of the estimated future net cash flows of that servicing strip. The lender may retain servicing or they may sell it. Lenders retaining servicing may want to **hedge** against fluctuations in value, since for example if interest rates drop then prepayment speeds for the serviced loans will increase.

The MBS may also have excess servicing that can be sold separately or retained. Excess servicing is what is left over after:

- coupon
- servicing
- credit losses
- trustee fees / administrative fees

Excess servicing is also referred to as the “interest only strip”, “IO strip”, or just the “IO”.

Big picture, the servicer is compensated via:

- the servicing fee
- income from the float
- ancillary income from fees (late fees, etc.)

Some lenders also do servicing; a lender may also value servicing to the extent that it may build a relationship with the borrower.

Concerning loan defaults, a good servicer will have a number of loss mitigation strategies if borrowers fall behind on payments due—forced sale is really the last resort. Approaches include:

- reinstatement / repayment plan
  - borrower had a temporary “blip”, is able to make payments
  - increase the monthly amount for a while until delinquency is repaid
- modification (permanent “mod”)
  - effectively a refi
  - many possibilities (interest rate, term, etc.)
- forbearance agreement
- partial MI advance claim payment
- deed in lieu (“turning in the keys”)
- short sale

## The Agencies

There are three agencies: **FNMA**, **FHLMC**, and **GNMA**.

The term GSE (government-sponsored enterprise) refers to FNMA or FHLMC.

## Fannie Mae

Fannie Mae, also called FNMA (from Federal National Mortgage Association), both guarantees MBSs/CMOs and invests in home loans, i.e., they are both guarantor and investor. As of their 2026Q1 10-Q they held over \$4.1T of HFI (held for investment) home loans plus a small amount of HFS (\$199M).

As of 2026, FNMA is operating under conservatorship with the FHFA (Federal Housing Finance Agency) acting as conservator. This conservatorship dates back to September 2008.

FNMA IPO'd in 1968 once the Housing and Urban Development Act of 1968 partitioned the old FHMA into a private piece and a government piece. The government piece created by the 1968 split is GNMA. The older FNMA was chartered in 1938.

## Ginnie Mae

GNMA was created in 1968 and issued the very first MBS in 1970.

GNMA-issued securities have an explicit credit guaranty from the US government. GNMA guarantees investors timely payment of principal and interest on those securities.

Most GNMA securities use as collateral single-family home loans insured by the federal government—specifically, per the Mortgage-Backed Securities (MBS) Guide 5500.3:

Each mortgage must be, and must remain, insured or guaranteed under the National Housing Act, Title V of the Housing Act of 1949, the Servicemen's Readjustment Act of 1944, chapter 37 of Title 38, United States Code, or section 184 of the Housing and Community Development Act of 1992, and must at all times comply with the requirements for obtaining and maintaining such insurance or guaranty.

Tying that back to insurers/guarantors ([Table 3](#)).

Authority	Insurer / Guarantor
National Housing Act	HUD FHA
Title V of the Housing Act of 1949	USDA RD
Servicemen's Readjustment Act of 1944	VA
Chapter 37 of Title 38, United States Code	VA
Section 184 of the Housing and Community Development Act of 1992	HUD PIH

Table 3: GNMA-eligible Mortgage Insurance and Guaranty Programs

Ginnie issues two types of MBS: GNMA I and GNMA II. There are differences, for example GNMA Is pay out on the 15th of the month, GNMA IIs on the 20th. As of 2026, most issuances are GNMA II, for example in May 2026 it was \$53B of GNMA-II versus only \$1.6B of GNMA I.

## Freddie Mac

FHLMC (Federal Home Loan Mortgage Corporation), like FNMA, serves the dual roles of guarantor and investor. As of their 2026Q1 10-Q they held over \$3.3T of HFI (held for investment) home loans plus a small amount of HFS (\$1.2B).

FHLMC was created in 1970.

Just as with FNMA, FHLMC is as of 2026 operating under the conservatorship of the FHFA.

## App and Lock

So we have **loans** + **collateral**, and we may **retain or sell** those loans. How exactly do we originate these loans to begin with?

It takes time to originate a loan, so we end up with a pipeline of home loan applications. Applicants may lock in the interest rate and other terms, so the lender will want to **hedge** the resulting interest rate risk.

If the applicant has locked in the proposed interest rate we have a lock, whereas a float is if there is no lock or the lock has expired. The interest rate is based on pricing which generally is under the **secondary marketing** function of the lender, for example published each morning under “rate sheets”.

The interest rate may also be dialed up or down via **points**.

## Points

Borrowers compensate the lender via fees, interest, and discount. With home loans, this discount is referred to as “points” and is quoted in terms of a % of the loan amount, e.g., 1 point means 1% of the loan amount. The borrower buys down the rate by paying points.

Terms vary over time and by lender, but for example buying 1 point on a \$300,000 loan would cost \$1,000 and might lower a 6% loan by 25 bps down to 5.75%.

Negative points work in the other direction, e.g., \$1,000 rebate at the cost of 25 bps on the note rate.

The interest rate—whether locked or not—together with certain other fixed charges such as pre-paid interest and points combine to form the “annual percentage rate” (APR).

## APR

Aswath Damodaran has a good definition of APR (annual percentage rate):

A rate that has to be cited with loans and mortgages in the United States. The rate incorporates an amortization of any fixed charges that have to be paid up front for the initiation of the loan.

Per 12 C.F.R. §1026.22:

The annual percentage rate is a measure of the cost of credit, expressed as a yearly rate, that relates the amount and timing of value received by the consumer to the amount and timing of payments made. The annual percentage rate shall be determined in accordance with either the actuarial method or the United States Rule method.

So we have two ways to calculate APR. Continuing in 12 C.F.R. §1026.22:

Under the actuarial method, at the end of each unit-period (or fractional unit-period) the unpaid balance of the amount financed is increased by the finance charge earned during that period and is decreased by the total payment (if any) made at the end of that period.

Then our other method differs if payments are less than the finance charge earned:

In contrast, under the United States Rule method, at the end of each payment period, the unpaid balance of the amount financed is increased by the finance charge earned during that payment period and is decreased by the payment made at the end of that payment period. If the payment is less than the finance charge earned, the adjustment of the unpaid balance of the amount financed is postponed until the end of the next payment period. If at that time the sum of the two payments is still less than the total earned finance charge for the two payment periods, the adjustment of the unpaid balance of the amount financed is postponed still another payment period, and so forth.

The idea behind APR is to combine the interest with discount (see [Points](#)) and other fixed fees to summarize the cost of borrowing in a single number. When an applicant gets a quote for a loan, that quote needs to include not just the interest rate but this all-in APR calculation.

The spread between APR and “Average Prime Offer Rates” (APOR) has implications for Qualified Mortgage (QM) status, Higher-Priced Mortgage Loan (HPML) status, and “high cost mortgage” thresholds under Home Ownership and Equity Protection Act (HOEPA) rules with details depending on when the loan was originated.

Once we have a proposed loan we move into underwriting.

## Docs and Underwriting

As of 2026, most applications are credit qualifying, credit referring to the willingness of the applicant to repay their obligations (usually demonstrated by a credit score). A typical start: the application kicks off with a 1003 (referring to the FNMA numbering for the URLA—the Uniform Residential Loan Application) and the tri-merge, i.e., when credit is pulled from the three credit reporting agencies. An alternative to using a score from the agencies is non-traditional credit. Credit is not a yes/no question so much as a scale: how conscientious is the applicant about paying their obligations as promised?

Most loan programs for most lenders will require that the ability to repay be demonstrated. This is a yes/no question: will the applicants be capable of repaying this proposed obligation? This determination is made by underwriters using documents as evidence.

Underwriters use income documentation to calculate a qualifying monthly income which is then compared with the proposed monthly obligations to answer the yes/no question about ability to repay. There are many types of documents. A few examples:

- IRS Forms
  - W-2 for payroll income
  - 1099s for interest, dividends, contract work, etc.
  - Tax returns, including 1040s, K-1s, Schedule C, etc.
- Paystubs
  - recent paystubs
  - year-to-date (YTD) paystubs
- Pre-close Verifications of Employment (PCVEs)
- Written Verifications of Employment (WVOEs)
- Court orders
- Divorce decrees
- Separation agreements
- Child support agreements
- Award letters
- Bank statements

The documents are used in combination, e.g., an award letter to verify pension amount and a bank statement to verify pension receipt.

To some extent, the underwriter can use more documents to increase the qualifying amount. For example, an applicant of retirement age might supply just bank statements and use their net deposit amount as the qualifying amount for their established Social Security Retirement. If a higher income was needed to qualify, the underwriter could then ask for the award letter so the full benefit amount could be used (whereas the deposits on the bank statement could be net the medicare premium or perhaps not reflect the very latest cost of living adjustment). If this was still not enough, the underwriter might be able to ask for tax returns

to verify that the Social Security payments were not subject to income tax and thus gross-up the net amount to get a higher qualifying amount. All three of these qualifying amounts are correct.

Qualifying income is expressed as a monthly amount and compared with monthly obligations. The most common way to compare is via the front-end and back-end ratios.

## Ratios

The front-end ratio compares income with the monthly housing expense (MHE). For an OO transaction the MHE is one and the same as the PITIA. For non-OO the MHE is the PITIA (if owned) or rent (if rented) from wherever it is the applicants live—possibly this is zero if the applicants live rent-free.

$$\text{Front-end Ratio} = \frac{\text{Monthly Housing Expense}}{\text{Monthly Income}}$$

The back-end ratio compares income with the total of all monthly obligations. The back-end ratio is also known as DTI (debt-to-income).

$$\text{Back-end Ratio} = \frac{\text{Monthly Obligations}}{\text{Monthly Income}}$$

Both of these ratios are unitless. Normally they are multiplied by 100, e.g., a ratio of 0.42 is quoted as being 42%. Higher front-end and back-end ratios indicate higher burdens, so lenders will set guideline limits as to the maximum ratio they will permit.

Note that these ratios use gross income, meaning income and payroll taxes are not taken into account. Certain VA loans use a more budget-like approach by calculating residual income using actual taxes and allowances for additional expenses based on family size and region.

## Residual Income

The VA Loan Analysis (Form 26-6393) permits the calculation of residual income, breaking down the monthly amounts as:

- gross salary/earnings
  - less federal income taxes
  - less state income taxes
  - less retirement or social security
  - less “other” (for anything else)
- net take-home pay
  - add pension or other net income
- total take-home pay
  - less monthly debts and obligations
  - less proposed shelter expenses
- balance available for family support

That remaining balance needs to pass the guideline based on family size and region.

On top of the residual income calculation, the VA Loan Analysis *also* includes the back-end ratio.

## Reserves

Underwriters may also look at reserves. Reserves are the assets remaining after closing. The reserve ratio (or more commonly, just “reserves”) counts the number of months of reserves, meaning how many months of subject property PITIA worth of savings will be borrowers have after the loan closes.

$$\text{Months of Reserves} = \frac{\text{Post-close Assets}}{\text{Monthly PITIA}}$$

Units here is months, so more is better.

## Hedging

Borrowers typically lock in the interest rate during the application process, for example for 60 or 90 days. This exposes the lender to the risk that interest rates increase. Why is this a problem? If rates go up, then the value of the cash flows from the loan goes down. Re-using the example of the Irvine, California median home sales price in March 2026 with a 20% down payment, let’s see the drop-off if we value the payments of 5% fixed-rate loan using 5.5% interest rate, i.e., as if interest rates increased from 5% to 5.5% between lock and fund.

```
# re-use the Irvine example
PrinBal <- 1510000 * 0.8
InterestRate <- 0.05
TermMonths <- 30 * 12

# difference between 5% and 5.5%
CalcAmortPrinBal(
  CalcAmortPmt(
    PrinBal, InterestRate / 12, TermMonths
  ), (InterestRate + 0.005) / 12, TermMonths
) - PrinBal
```

```
## [1] -65884.67
```

A standard approach to mitigate pipeline risk is to for the **secondary marketing** function of the lender to hedge the interest rate risk inherent in having a pipeline of locked applications. Ideally the lender can hedge in such a way as to be indifferent to changes in interest rates (indifferent from an pipeline risk perspective). Some considerations:

- balance of the pipeline times the expected pull-through rate
- duration of the pipeline vs. the TBAs (see **Duration**)
- convexity
- could sell forward through TBAs (see **Secondary Market**)
  - mandatory vs. best effort
- could use options on forward sale of MBSs
- US Treasuries (useful for duration risk)
- interest rate swaps (useful duration risk)
- interest rate swaptions (future date, useful for convexity risk)

What do we mean by “balance of the pipeline times the expected pull-through rate”? By pull-through rate we mean, of the locked pipeline, how much is actually going to fund? Oversimplifying just to illustrate, if

the lender has a locked pipeline of \$500M of Conventional Conforming 5% 30-year apps, and we estimate a pull-through rate of 60%, then if \$300M (60% times \$500M) is sold forward the lender is now indifferent as to whether interest rates go up or down or stay the same: the lender expects \$300M of Conventional Conforming 5% 30-year apps and has already sold that \$300M.

Consider that by selling forward we've introduced a different risk. The *OCC Comptroller's Handbook* chapter on mortgage banking (2014) summarizes this nicely:

Locked-in pipeline commitments subject the bank to price risk because the bank must make the loan at the locked rate and terms, regardless of market rate changes. To the extent the bank has hedged the loan through a forward sale to an investor, not closing the loan during the rate-lock period could expose the bank to price risk if it is unable to deliver the loan to an investor as contracted.

And what happens if rates drop? Again quoting the handbook:

Effectively hedging the pipeline depends on accurately predicting and measuring the fallout and pull-through percentages. If interest rates drop and fallout is greater than expected, the bank may not be able to meet its forward sales commitments to investors. As a result, the bank may be forced to purchase needed loans in the secondary market at unfavorable prices or pay a pair-off fee, which equals the price impact the adverse market movement had on the shortfall under the forward sale commitment.

Thus, a complication of estimating pull-through is that the pull-through rate is going to change when interest rates change. Pull-through will increase if interest rates go up since borrowers are incentivized to close the loan under the locked-in rate; conversely, if interest rates go down then borrowers have a strong incentive to seek a lower rate and the pull-through rate drops. Pull-through will also be higher for applications that are further along in the process any may vary based on other characteristics (e.g., higher or lower pull-through based on **purpose**, **occupancy**, etc.). Lenders will typically model the pipeline using these application characteristics so as to better hedge the risks.

So we can see that even this most basic hedge—selling forward TBAs—is not a simple matter.

## Duration

What do we mean by “duration of the pipeline”? In general, duration is the name for weighted maturity. As Aswath Damodaran puts it:

Weighted maturity of all the cash flows on an asset or liability.

Duration in the context of fixed income usually refers to the weighted average time to each payment, also called the Macaulay duration, from which we can derive the modified duration. Duration may also refer to an “effective duration” that takes into account prepayments.

Let's illustrate Macaulay duration using that example loan for 80% of the median Irvine home price. The loan payments will be our cash flows. For PV we'll use the interest rate to discount and assume the cash flow is `MonthNum` number of months in the future.

```
# continuing with the Irvine example
tCashFlows <- CalcAmortTable(PrinBal, InterestRate, TermMonths)[, .(MonthNum, PmtAmt=PIAmt)]

# add PV of payment as a column
tCashFlows[, PmtPVAmt := PmtAmt / (1 + InterestRate / 12)^MonthNum]
```

We should double check our math before moving to the next step—do we get back a PV equal to the loan amount?

```
sum(tCashFlows$PmtPVAmt)
```

```
## [1] 1208000
```

So far so good. Now:

- Reuse annual interest rate  $r$  as our discount factor for present value
- Reuse  $N$  as the term in months
- Let  $V_1, V_2, \dots, V_N$  be the present values of each payment  $P_n$ ,  $n \in 1 \dots N$
- Let  $D$  be our unknown duration (units will be months)

Our duration  $D$  is the weighted average time to each payment:

$$D = \frac{\sum_{n=1}^N nV_n}{\sum_{n=1}^N V_n}$$

So the duration for our loan works out as:

```
DurationMonths <- tCashFlows[, sum(MonthNum * PmtPVAmt) / sum(PmtPVAmt)]
sprintf("Duration is %.1f months (%.2f years)",
        DurationMonths, DurationMonths / 12)
```

```
## [1] "Duration is 137.2 months (11.43 years)"
```

So far this ignores the effect of prepayments, i.e., we're just measuring duration using scheduled payments. Just the same, we can see how the duration falls quite a bit under the halfway point of the 30 year term.

Next up is what is called modified duration. With modified duration in general what we're looking for is a negative normalized first derivative of price with respect to yield—we normalize by price, ending up with the negative ratio of the derivative of price with respect to yield over the price, which in our context means we want:

$$D_{mod} = -\frac{1}{V} \frac{dV}{dr}$$

We're treating the value  $V$  as a function of rate  $r$  here. The negation can make usage more intuitive, and regardless it's a longstanding convention. Note that whereas  $D$  was in units of months, our  $D_{mod}$  will be unitless.

To find modified duration, the short story is we multiply by our ratio  $R$  (the ratio between terms of the geometric series) and divide by 12 to convert monthly  $D$  to annual  $D$  (call it  $D_{ann}$ ), but let's step through to justify that claim.

Recall from [level payments](#) that when our  $P_1, P_2, \dots, P_N$  are equal, we have just  $P$  as **the** level payment, and our loan  $L$  comes out to this finite geometric series:

$$L = \sum_{n=1}^N PR^n$$

If the payments are not necessarily level, we can re-write this to use  $P_1, P_2, \dots, P_N$ , and instead of using  $L$  for loan amount let's switch to  $V$  to remind us we're talking about value of the  $V_1, V_2, \dots, V_N$  cash flows now:

$$V = \sum_{n=1}^N P_n R^n$$

Likewise, since  $V_1, V_2, \dots, V_N$  are the present values of each payment  $P_n$ ,  $n \in 1 \dots N$ , we use the following for any specific  $V_n$ :

$$V_n = P_n R^n = P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n, \quad n \in 1 \dots N$$

We're looking for  $-\frac{1}{V} \frac{dV}{dr}$ , so to start we need to crack open that  $R$  and differentiate:

$$\begin{aligned} V &= \sum_{n=1}^N P_n R^n \\ &= \sum_{n=1}^N P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n \\ &= \sum_{n=1}^N P_n \left( 1 + \frac{r}{12} \right)^{-n} \\ \frac{dV}{dr} &= \frac{d}{dr} \left[ \sum_{n=1}^N P_n \left( 1 + \frac{r}{12} \right)^{-n} \right] && \frac{d}{dr} \text{ both sides} \\ &= \sum_{n=1}^N P_n \frac{d}{dr} \left[ \left( 1 + \frac{r}{12} \right)^{-n} \right] && \text{linearity} \\ &= \sum_{n=1}^N P_n - n \left( 1 + \frac{r}{12} \right)^{-n-1} \frac{d}{dr} \left[ 1 + \frac{r}{12} \right] && \text{chain rule} \\ &= \sum_{n=1}^N P_n - n \left( 1 + \frac{r}{12} \right)^{-n-1} \frac{1}{12} \\ &= - \sum_{n=1}^N P_n \frac{n}{12} \left( 1 + \frac{r}{12} \right)^{-n-1} \end{aligned}$$

If we factor out a  $\left( 1 + \frac{r}{12} \right)^{-1}$  and divide both sides by  $-V$  we find our friend  $D = \frac{\sum_{n=1}^N n V_n}{\sum_{n=1}^N V_n}$  in the right hand side:

$$\begin{aligned} \frac{dV}{dr} &= - \left( \frac{1}{1 + \frac{r}{12}} \right) \sum_{n=1}^N P_n \frac{n}{12} \left( 1 + \frac{r}{12} \right)^{-n} \\ &= - \left( \frac{1}{1 + \frac{r}{12}} \right) \sum_{n=1}^N \frac{n}{12} P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n \\ -\frac{1}{V} \frac{dV}{dr} &= \left( \frac{1}{1 + \frac{r}{12}} \right) \frac{\sum_{n=1}^N \frac{n}{12} P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n}{V} && \text{divide by } -V \\ &= \left( \frac{1}{1 + \frac{r}{12}} \right) \frac{\sum_{n=1}^N \frac{n}{12} P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n}{\sum_{n=1}^N P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n} && \text{sub } V = \sum_{n=1}^N P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n \\ &= \left( \frac{1}{1 + \frac{r}{12}} \right) \left( \frac{1}{12} \right) \frac{\sum_{n=1}^N n P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n}{\sum_{n=1}^N P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n} && \text{factor out } \frac{1}{12} \\ &= \left( \frac{1}{1 + \frac{r}{12}} \right) \left( \frac{1}{12} \right) \frac{\sum_{n=1}^N n V_n}{\sum_{n=1}^N V_n} && \text{sub } V_n = P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n \end{aligned}$$

Now substitute in  $D$  and we see that  $D$  and  $D_{mod}$  are related by  $R$  and a factor of 12:

$$\begin{aligned}
 -\frac{1}{V} \frac{dV}{dr} &= \left( \frac{1}{1 + \frac{r}{12}} \right) \left( \frac{1}{12} \right) \frac{\sum_{n=1}^N nV_n}{\sum_{n=1}^N V_n} && \text{continuing} \\
 &= \left( \frac{1}{1 + \frac{r}{12}} \right) \left( \frac{1}{12} \right) D && \text{sub } D = \frac{\sum_{n=1}^N nV_n}{\sum_{n=1}^N V_n} \\
 &= R \left( \frac{1}{12} \right) D && \text{sub } R = \frac{1}{1 + \frac{r}{12}} \\
 &= \left( \frac{R}{12} \right) D
 \end{aligned}$$

Alternatively, a *yearly* duration  $D_{ann}$  is related to  $D_{mod}$  by just that ratio  $R$ . In any case, upshot is we can now justify:

$$\begin{aligned}
 D_{mod} &= \left( \frac{R}{12} \right) D \\
 &= \left( \frac{1}{12} \right) \frac{D}{1 + \frac{r}{12}} \\
 &= \frac{D_{ann}}{1 + \frac{r}{12}}
 \end{aligned}$$

So the modified duration for our loan cash flow comes out to:

```
ModifiedDuration <- DurationMonths / (1 + InterestRate / 12) / 12
sprintf("Modified Duration is %.2f", ModifiedDuration)
```

```
## [1] "Modified Duration is 11.38"
```

Let's put this to the test to check our work. If this really is the negative and normalized first derivative, we should be able to use modified duration to approximate the change in  $V$  for a small change in  $r$ . Our modified duration is normalized by  $V$  and negated, so our approximation of  $\Delta V$  will be need to multiply modified duration by  $-V$ . Let's increase the example interest rate by an eighth and see:

```
# increase r by an eighth
DeltaR = 0.00125
tCashFlows[,PmtNewPVAmt:=PmtAmt / (1 + (InterestRate+DeltaR) / 12)^MonthNum]

# estimate the change in V using a first order linear approximation
ApproxDeltaV = sum(tCashFlows$PmtPVAmt) * -1 * ModifiedDuration * DeltaR

# for printing nicely format comparison
PrintResultsFromApprox <- function(
  PV, NewPV, InterestRate, DeltaR, ApproxDeltaV) {
  # print results
  cat(
    sprintf("Approximating a change from %.3f%% to %.3f%%:\n",
            InterestRate*100, (InterestRate+DeltaR)*100),
    sprintf(" Before           = %9.0f", PV),
    "\n",
    sprintf(" After (Actual)         = %9.0f", NewPV),
    "\n",
    sprintf(" After (Approximated) = %9.0f", PV + ApproxDeltaV),
```

```

"\n",
sprintf(" Error (Abs)           = %12.2f", PV + ApproxDeltaV - NewPV),
"\n",
sprintf(" Error (Rel)           = %8.3f%%",
        (PV + ApproxDeltaV - NewPV)/NewPV * 100),
"\n"
)
}

# display results
PrintResultsFromApprox(sum(tCashFlows$PmtPVAmt),
                       sum(tCashFlows$PmtNewPVAmt),
                       InterestRate, DeltaR, ApproxDeltaV)

```

```

## Approximating a change from 5.000% to 5.125%:
## Before = 1208000
## After (Actual) = 1190994
## After (Approximated) = 1190809
## Error (Abs) = -184.60
## Error (Rel) = -0.015%

```

That is indeed very close, a good sign that our calculation is correct.

Duration and modified duration are interesting, but what's the bottom line from a hedging perspective? We need to consider that the duration of the pipeline may not exactly match the duration of the TBAs sold forward, meaning that a change in interest rates will not have exactly the same effect.

What happens for approximations that are not so close to the tangent point? Let's try a shift of 100 bps, i.e., from 5% to 6%.

```

# increase r by 100 bps
DeltaR = 0.01
tCashFlows[,PmtNewPVAmt:=PmtAmt / (1 + (InterestRate+DeltaR) / 12)^MonthNum]

# estimate the change in V using a first order linear approximation
ApproxDeltaV = sum(tCashFlows$PmtPVAmt) * -1 * ModifiedDuration * DeltaR

# display results
PrintResultsFromApprox(sum(tCashFlows$PmtPVAmt),
                       sum(tCashFlows$PmtNewPVAmt),
                       InterestRate, DeltaR, ApproxDeltaV)

```

```

## Approximating a change from 5.000% to 6.000%:
## Before = 1208000
## After (Actual) = 1081611
## After (Approximated) = 1070472
## Error (Abs) = -11138.76
## Error (Rel) = -1.030%

```

Now our first order approximation is off by a little over 1%. It's not as close of an estimate. What about a second order approximation? This brings us to the topic of **convexity**.

## Convexity

What did we mean by “convexity” in the bulleted list of hedging considerations? Convexity is the normalized second derivative of price with respect to yield, which in our context means we want:

$$C = \frac{1}{V} \frac{d^2V}{dr^2}$$

Let’s see what that will be. Continuing from the first derivative (see [Duration](#) above):

$$\begin{aligned} \frac{dV}{dr} &= - \sum_{n=1}^N P_n \frac{n}{12} \left(1 + \frac{r}{12}\right)^{-n-1} && \text{(see Duration above)} \\ \frac{d^2V}{dr^2} &= \frac{d}{dr} \left[ - \sum_{n=1}^N P_n \frac{n}{12} \left(1 + \frac{r}{12}\right)^{-n-1} \right] && \frac{d}{dr} \text{ both sides} \\ &= - \sum_{n=1}^N P_n \frac{n}{12} \frac{d}{dr} \left[ \left(1 + \frac{r}{12}\right)^{-n-1} \right] && \text{linearity} \\ &= - \sum_{n=1}^N P_n \frac{n}{12} (-n-1) \left(1 + \frac{r}{12}\right)^{-n-2} \frac{d}{dr} \left[ 1 + \frac{r}{12} \right] && \text{chain rule} \\ &= - \sum_{n=1}^N P_n \frac{n}{12} (-n-1) \left(1 + \frac{r}{12}\right)^{-n-2} \frac{1}{12} \\ &= - \sum_{n=1}^N P_n \frac{n}{12^2} (-n-1) \left(1 + \frac{r}{12}\right)^{-n-2} && \text{combining } \frac{1}{12} \text{ terms} \\ &= - \sum_{n=1}^N P_n \frac{n(-n-1)}{12^2} \left(1 + \frac{r}{12}\right)^{-n-2} \\ &= \sum_{n=1}^N P_n \frac{n(n+1)}{12^2} \left(1 + \frac{r}{12}\right)^{-n-2} && \text{negations cancel} \\ &= \sum_{n=1}^N P_n \frac{n(n+1)}{12^2 \left(1 + \frac{r}{12}\right)^{n+2}} && \text{move } \left(1 + \frac{r}{12}\right)^{-n-2} \text{ to denominator} \end{aligned}$$

Then we normalize and after a few movements find a familiar  $P_n \left(\frac{1}{1+\frac{r}{12}}\right)^n$ :

$$\begin{aligned} C &= \frac{1}{V} \frac{d^2V}{dr^2} \\ &= \frac{1}{V} \sum_{n=1}^N P_n \frac{n(n+1)}{12^2 \left(1 + \frac{r}{12}\right)^{n+2}} && \frac{d^2V}{dr^2} \text{ from above} \\ &= \frac{1}{12^2 V} \sum_{n=1}^N P_n \frac{n(n+1)}{\left(1 + \frac{r}{12}\right)^{n+2}} && \text{pull out the } \frac{1}{12^2} \\ &= \frac{1}{12^2 V} \sum_{n=1}^N P_n \frac{n(n+1)}{\left(1 + \frac{r}{12}\right)^n \left(1 + \frac{r}{12}\right)^2} && \text{split } n \text{ and } +2 \\ &= \frac{1}{12^2 \left(1 + \frac{r}{12}\right)^2 V} \sum_{n=1}^N P_n \frac{n(n+1)}{\left(1 + \frac{r}{12}\right)^n} && \text{pull out the } \frac{1}{\left(1 + \frac{r}{12}\right)^2} \\ &= \frac{1}{12^2 \left(1 + \frac{r}{12}\right)^2 V} \sum_{n=1}^N P_n \left(\frac{1}{1 + \frac{r}{12}}\right)^n n(n+1) \end{aligned}$$

We can sub in  $V_n$  to get:

$$C = \frac{1}{12^2(1 + \frac{r}{12})^2V} \sum_{n=1}^N P_n \left( \frac{1}{1 + \frac{r}{12}} \right)^n n(n+1) \quad \text{continuing}$$

$$= \frac{1}{12^2(1 + \frac{r}{12})^2V} \sum_{n=1}^N V_n n(n+1) \quad \text{sub } V_n = \left( \frac{1}{1 + \frac{r}{12}} \right)^n$$

Now to code that up.

```
Convexity <- sum(tCashFlows$PmtPVAmt
                * tCashFlows$MonthNum
                * (tCashFlows$MonthNum + 1)) /
  (12^2 * (1 + InterestRate/12)^2 * sum(tCashFlows$PmtPVAmt))
sprintf("Convexity is %.2f", Convexity)
```

```
## [1] "Convexity is 197.29"
```

Now to test it. If this really is the second derivative, then we ought to improve the accuracy of our approximation. Our first order approximation was  $\text{sum}(\text{tCashFlows}\$PmtPVAmt) * -1 * \text{ModifiedDuration} * \text{DeltaR}$ , now we add in the second order component to get  $\text{sum}(\text{tCashFlows}\$PmtPVAmt) * (-1 * \text{ModifiedDuration} * \text{DeltaR} + (\text{Convexity} * \text{DeltaR}^2) / 2)$ . Will our second order approximation improve upon the first order approximation?

```
# increase r by 100 bps
DeltaR = 0.01
tCashFlows[,PmtNewPVAmt:=PmtAmt / (1 + (InterestRate+DeltaR) / 12)^MonthNum]

# estimate the change in V using a second order linear approximation
ApproxDeltaV = sum(tCashFlows$PmtPVAmt) * (-1 * ModifiedDuration * DeltaR +
                                             (Convexity * DeltaR^2) / 2)

# display results
PrintResultsFromApprox(sum(tCashFlows$PmtPVAmt),
                       sum(tCashFlows$PmtNewPVAmt),
                       InterestRate, DeltaR, ApproxDeltaV)
```

```
## Approximating a change from 5.000% to 6.000%:
## Before = 1208000
## After (Actual) = 1081611
## After (Approximated) = 1082389
## Error (Abs) = 777.48
## Error (Rel) = 0.072%
```

Much better—this is a good sign that we’ve calculated the second derivative correctly. Now let’s see how close a second order approximation gets us on that earlier test we did.

```
# increase r by an eighth
DeltaR = 0.00125
tCashFlows[,PmtNewPVAmt:=PmtAmt / (1 + (InterestRate+DeltaR) / 12)^MonthNum]

# estimate the change in V using a second order linear approximation
```

```

ApproxDeltaV = sum(tCashFlows$PmtPVAmt) * (-1 * ModifiedDuration * DeltaR +
              (Convexity * DeltaR^2) / 2)

```

```
# display results
```

```

PrintResultsFromApprox(sum(tCashFlows$PmtPVAmt),
                       sum(tCashFlows$PmtNewPVAmt),
                       InterestRate, DeltaR, ApproxDeltaV)

```

```
## Approximating a change from 5.000% to 5.125%:
```

```

## Before = 1208000
## After (Actual) = 1190994
## After (Approximated) = 1190995
## Error (Abs) = 1.59
## Error (Rel) = 0.000%

```

Within \$2 on a \$1.2M amount—very nice.

Above math and code gives us a flavor of duration and convexity. In practice with duration and convexity we would not be ignoring the effect of prepayments and would include some kind of assumption, for instance 100% PSA, or more likely some more robust prepayment model.

So we’ve touched on the pipeline and estimating pull-through and considering duration & convexity. What about “mandatory vs. best effort” in regards to forward sales—what is that about?

## Forward Sales Agreements

As mentioned above, an important tool in the hedging toolbox is the forward sale of TBAs. This can be via either mandatory (aka “firm”) forward sales agreements or best effort (aka optional) forward sales agreements. What do we mean by “mandatory vs. best effort” when selling forward? By mandatory we mean (quoting again):

Under mandatory contracts, the bank is obligated to deliver a specific dollar volume of mortgages to the investor. If the bank is unable to deliver the required volume within the specified commitment period, it may be required to either purchase loans from other sources or pay the investor a pair-off fee.

Best effort:

On a best efforts basis, the bank locks in an individual loan commitment and simultaneously contracts to sell it for future delivery at the time the rate lock is granted to an applicant. The terms of this forward sale are identical to those of the rate lock, but the selling bank only agrees to deliver the loan on a best efforts basis—that is, only if the loan closes. The price risk in this arrangement is borne solely by the purchasing institution. Best efforts contracts normally yield a lower selling price than mandatory contracts, which contain more uncertainty and risk.

## Options

Another tool in the toolbox is options. As the *OCC Comptroller’s Handbook* puts it:

Many banks use a combination of forward sales and options to offset price risk. For example, a bank might anticipate closing 70 percent of the loans in the pipeline under a most likely scenario, 80 percent if rates rise significantly, but only 65 percent if rates decline. To hedge this risk profile the bank could sell forward an amount equal to 70 percent of the pipeline, purchase call options to provide coverage on 5 percent of the pipeline if rates fall, and sell futures or purchase put options to cover the other 10 percent of the pipeline if rates rise. This method hedges the pipeline so long as 65 percent to 80 percent of the loans close. Using options

to hedge pipeline risk can be effective, but is also more expensive than using forward sale contracts alone.

## Beyond Locked Pipeline

Consider also that in addition to hedging the pipeline that the lender may have a “warehouse” of HFS on their books as well. The lender will want to hedge the **MSRs**, too. For example, the value of MSRs tends to increase in rising rate environments to the extent that borrowers have less of a refi incentive.

We can see how we end up with so many moving pieces. Ideally a lender pulls these all together into an effective well-optimized hedge:

Hedge optimization pulls together all existing hedge positions; current best execution for each loan; potential forward sale and option instruments for every coupon, expiration, and strike price; and bid-ask spreads for all potential trades and preferences for hedging.

## Closing

Closing refers to the last step of the application where, among other activities, the **note**, **security instrument**, and any other required documents are signed by the borrowers. The *OCC Comptroller’s Handbook* describes it as follows.

After the underwriting unit approves a loan, the closing unit ensures that the loan is properly closed and settled, including providing consumers with all required disclosures, and that the bank has all required documentation. Closings may be performed by an internal loan closing unit or by title companies or attorneys acting as agents for the bank. Whether a bank employee or agent performs the closing, all required documents should be obtained before disbursing any loan proceeds.

Some states require a licensed attorney be present at closing. In all states, some documents will need to be notarized.

Funds may be wired the same day depending on the specific type of home loan, or there may be a 3 business day waiting period due to the right of rescission. Per 12 C.F.R. §1026.23 (a)(1):

In a credit transaction in which a security interest is or will be retained or acquired in a consumer’s principal dwelling, each consumer whose ownership interest is or will be subject to the security interest shall have the right to rescind the transaction, except for transactions described in paragraph (f) of this section. For purposes of this section, the addition to an existing obligation of a security interest in a consumer’s principal dwelling is a transaction. The right of rescission applies only to the addition of the security interest and not the existing obligation.

The right to rescind only applies to certain refinances or home equity transactions. Per 12 C.F.R. §1026.23 (f):

The right to rescind does not apply to the following:

- (1) A residential mortgage transaction.
- (2) A refinancing or consolidation by the same creditor of an extension of credit already secured by the consumer’s principal dwelling. The right of rescission shall apply, however, to the extent the new amount financed exceeds the unpaid principal balance, any earned unpaid finance charge on the existing debt, and amounts attributed solely to the costs of the refinancing or consolidation.

In (a)(3)(i) we get some clarity around the 3 business day rule:

The consumer may exercise the right to rescind until midnight of the third business day following consummation, delivery of the notice required by paragraph (b) of this section [the notice of right to rescind], or delivery of all material disclosures, whichever occurs last. If the required notice or material disclosures are not

delivered, the right to rescind shall expire 3 years after consummation, upon transfer of all of the consumer's interest in the property, or upon sale of the property, whichever occurs first.

Most fees are paid at closing, for example origination fees. Any **per-diem interest** due would normally be paid at closing.