final_project

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Packages Used

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --

## v ggplot2 3.3.4     v purrr   0.3.4
## v tibble  3.1.2     v dplyr   1.0.6
## v tidyr   1.1.3     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1

## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(randomForest)
```

```
## randomForest 4.6-14

## Type rfNews() to see new features/changes/bug fixes.

##
## Attaching package: 'randomForest'

## The following object is masked from 'package:dplyr':
##
##     combine

## The following object is masked from 'package:ggplot2':
##
##     margin
```

```
library(caret)
```

```
## Loading required package: lattice

##
## Attaching package: 'caret'
```

```
## The following object is masked from 'package:purrr':
##
##     lift
```

```
library(ggpubr)
```

Research Question

We are attempting to explore the relationship between various features of a house (ex. number of rooms, square footage, year built, etc.) on the future value of the house.

Data Source and Definitions

The USA Housing Dataset from Kaggle provides data regarding sales prices with respect to various houses in the US. It has 81 features describing each record for 1460 records.

```
dat <- read.csv("housing_data.csv")
str(dat)
```

```
## 'data.frame':    1460 obs. of  81 variables:
##  $ Id           : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ MSSubClass   : int  60 20 60 70 60 50 20 60 50 190 ...
##  $ MSZoning     : chr  "RL" "RL" "RL" "RL" ...
##  $ LotFrontage  : int  65 80 68 60 84 85 75 NA 51 50 ...
##  $ LotArea      : int  8450 9600 11250 9550 14260 14115 10084 10382 6120 7420 ...
##  $ Street       : chr  "Pave" "Pave" "Pave" "Pave" ...
##  $ Alley        : chr  NA NA NA NA ...
##  $ LotShape     : chr  "Reg" "Reg" "IR1" "IR1" ...
##  $ LandContour  : chr  "Lvl" "Lvl" "Lvl" "Lvl" ...
##  $ Utilities    : chr  "AllPub" "AllPub" "AllPub" "AllPub" ...
##  $ LotConfig    : chr  "Inside" "FR2" "Inside" "Corner" ...
##  $ LandSlope    : chr  "Gtl" "Gtl" "Gtl" "Gtl" ...
##  $ Neighborhood : chr  "CollgCr" "Veenker" "CollgCr" "Crawfor" ...
##  $ Condition1   : chr  "Norm" "Feedr" "Norm" "Norm" ...
##  $ Condition2   : chr  "Norm" "Norm" "Norm" "Norm" ...
##  $ BldgType     : chr  "1Fam" "1Fam" "1Fam" "1Fam" ...
##  $ HouseStyle   : chr  "2Story" "1Story" "2Story" "2Story" ...
##  $ OverallQual  : int  7 6 7 7 8 5 8 7 7 5 ...
##  $ OverallCond  : int  5 8 5 5 5 5 5 6 5 6 ...
##  $ YearBuilt    : int  2003 1976 2001 1915 2000 1993 2004 1973 1931 1939 ...
##  $ YearRemodAdd : int  2003 1976 2002 1970 2000 1995 2005 1973 1950 1950 ...
##  $ RoofStyle    : chr  "Gable" "Gable" "Gable" "Gable" ...
##  $ RoofMatl     : chr  "CompShg" "CompShg" "CompShg" "CompShg" ...
##  $ Exterior1st  : chr  "VinylSd" "MetalSd" "VinylSd" "Wd Sdng" ...
##  $ Exterior2nd  : chr  "VinylSd" "MetalSd" "VinylSd" "Wd Shng" ...
##  $ MasVnrType   : chr  "BrkFace" "None" "BrkFace" "None" ...
##  $ MasVnrArea   : int  196 0 162 0 350 0 186 240 0 0 ...
##  $ ExterQual    : chr  "Gd" "TA" "Gd" "TA" ...
##  $ ExterCond    : chr  "TA" "TA" "TA" "TA" ...
##  $ Foundation   : chr  "PConc" "CBlock" "PConc" "BrkTil" ...
```

```
##  $ BsmtQual     : chr  "Gd" "Gd" "Gd" "TA" ...
##  $ BsmtCond     : chr  "TA" "TA" "TA" "Gd" ...
##  $ BsmtExposure : chr  "No" "Gd" "Mn" "No" ...
##  $ BsmtFinType1 : chr  "GLQ" "ALQ" "GLQ" "ALQ" ...
##  $ BsmtFinSF1   : int  706 978 486 216 655 732 1369 859 0 851 ...
##  $ BsmtFinType2 : chr  "Unf" "Unf" "Unf" "Unf" ...
##  $ BsmtFinSF2   : int  0 0 0 0 0 0 0 32 0 0 ...
##  $ BsmtUnfSF    : int  150 284 434 540 490 64 317 216 952 140 ...
##  $ TotalBsmtSF  : int  856 1262 920 756 1145 796 1686 1107 952 991 ...
##  $ Heating      : chr  "GasA" "GasA" "GasA" "GasA" ...
##  $ HeatingQC    : chr  "Ex" "Ex" "Ex" "Gd" ...
##  $ CentralAir   : chr  "Y" "Y" "Y" "Y" ...
##  $ Electrical   : chr  "SBrkr" "SBrkr" "SBrkr" "SBrkr" ...
##  $ X1stFlrSF    : int  856 1262 920 961 1145 796 1694 1107 1022 1077 ...
##  $ X2ndFlrSF    : int  854 0 866 756 1053 566 0 983 752 0 ...
##  $ LowQualFinSF : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ GrLivArea    : int  1710 1262 1786 1717 2198 1362 1694 2090 1774 1077 ...
##  $ BsmtFullBath : int  1 0 1 1 1 1 1 1 0 1 ...
##  $ BsmtHalfBath : int  0 1 0 0 0 0 0 0 0 0 ...
##  $ FullBath     : int  2 2 2 1 2 1 2 2 2 1 ...
##  $ HalfBath     : int  1 0 1 0 1 1 0 1 0 0 ...
##  $ BedroomAbvGr : int  3 3 3 3 4 1 3 3 2 2 ...
##  $ KitchenAbvGr : int  1 1 1 1 1 1 1 1 2 2 ...
##  $ KitchenQual  : chr  "Gd" "TA" "Gd" "Gd" ...
##  $ TotRmsAbvGrd : int  8 6 6 7 9 5 7 7 8 5 ...
##  $ Functional   : chr  "Typ" "Typ" "Typ" "Typ" ...
##  $ Fireplaces   : int  0 1 1 1 1 0 1 2 2 2 ...
##  $ FireplaceQu  : chr  NA "TA" "TA" "Gd" ...
##  $ GarageType   : chr  "Attchd" "Attchd" "Attchd" "Detchd" ...
##  $ GarageYrBlt  : int  2003 1976 2001 1998 2000 1993 2004 1973 1931 1939 ...
##  $ GarageFinish : chr  "RFn" "RFn" "RFn" "Unf" ...
##  $ GarageCars   : int  2 2 2 3 3 2 2 2 2 1 ...
##  $ GarageArea   : int  548 460 608 642 836 480 636 484 468 205 ...
##  $ GarageQual   : chr  "TA" "TA" "TA" "TA" ...
##  $ GarageCond   : chr  "TA" "TA" "TA" "TA" ...
##  $ PavedDrive   : chr  "Y" "Y" "Y" "Y" ...
##  $ WoodDeckSF   : int  0 298 0 0 192 40 255 235 90 0 ...
##  $ OpenPorchSF  : int  61 0 42 35 84 30 57 204 0 4 ...
##  $ EnclosedPorch: int  0 0 0 272 0 0 0 228 205 0 ...
##  $ X3SsnPorch   : int  0 0 0 0 0 320 0 0 0 0 ...
##  $ ScreenPorch  : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ PoolArea     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ PoolQC       : chr  NA NA NA NA ...
##  $ Fence        : chr  NA NA NA NA ...
##  $ MiscFeature  : chr  NA NA NA NA ...
##  $ MiscVal      : int  0 0 0 0 0 700 0 350 0 0 ...
##  $ MoSold       : int  2 5 9 2 12 10 8 11 4 1 ...
##  $ YrSold       : int  2008 2007 2008 2006 2008 2009 2007 2009 2008 2008 ...
##  $ SaleType     : chr  "WD" "WD" "WD" "WD" ...
##  $ SaleCondition: chr  "Normal" "Normal" "Normal" "Abnorml" ...
##  $ SalePrice    : int  208500 181500 223500 140000 250000 143000 307000 200000 129900 118000 ...
```

We don't care about the Id column, so we will drop it.

```r
dat <- dat[,-c(1)]
str(dat)
```

```
## 'data.frame':    1460 obs. of  80 variables:
##  $ MSSubClass   : int  60 20 60 70 60 50 20 60 50 190 ...
##  $ MSZoning     : chr  "RL" "RL" "RL" "RL" ...
##  $ LotFrontage  : int  65 80 68 60 84 85 75 NA 51 50 ...
##  $ LotArea      : int  8450 9600 11250 9550 14260 14115 10084 10382 6120 7420 ...
##  $ Street       : chr  "Pave" "Pave" "Pave" "Pave" ...
##  $ Alley        : chr  NA NA NA NA ...
##  $ LotShape     : chr  "Reg" "Reg" "IR1" "IR1" ...
##  $ LandContour  : chr  "Lvl" "Lvl" "Lvl" "Lvl" ...
##  $ Utilities    : chr  "AllPub" "AllPub" "AllPub" "AllPub" ...
##  $ LotConfig    : chr  "Inside" "FR2" "Inside" "Corner" ...
##  $ LandSlope    : chr  "Gtl" "Gtl" "Gtl" "Gtl" ...
##  $ Neighborhood : chr  "CollgCr" "Veenker" "CollgCr" "Crawfor" ...
##  $ Condition1   : chr  "Norm" "Feedr" "Norm" "Norm" ...
##  $ Condition2   : chr  "Norm" "Norm" "Norm" "Norm" ...
##  $ BldgType     : chr  "1Fam" "1Fam" "1Fam" "1Fam" ...
##  $ HouseStyle   : chr  "2Story" "1Story" "2Story" "2Story" ...
##  $ OverallQual  : int  7 6 7 7 8 5 8 7 7 5 ...
##  $ OverallCond  : int  5 8 5 5 5 5 5 6 5 6 ...
##  $ YearBuilt    : int  2003 1976 2001 1915 2000 1993 2004 1973 1931 1939 ...
##  $ YearRemodAdd : int  2003 1976 2002 1970 2000 1995 2005 1973 1950 1950 ...
##  $ RoofStyle    : chr  "Gable" "Gable" "Gable" "Gable" ...
##  $ RoofMatl     : chr  "CompShg" "CompShg" "CompShg" "CompShg" ...
##  $ Exterior1st  : chr  "VinylSd" "MetalSd" "VinylSd" "Wd Sdng" ...
##  $ Exterior2nd  : chr  "VinylSd" "MetalSd" "VinylSd" "Wd Shng" ...
##  $ MasVnrType   : chr  "BrkFace" "None" "BrkFace" "None" ...
##  $ MasVnrArea   : int  196 0 162 0 350 0 186 240 0 0 ...
##  $ ExterQual    : chr  "Gd" "TA" "Gd" "TA" ...
##  $ ExterCond    : chr  "TA" "TA" "TA" "TA" ...
##  $ Foundation   : chr  "PConc" "CBlock" "PConc" "BrkTil" ...
##  $ BsmtQual     : chr  "Gd" "Gd" "Gd" "TA" ...
##  $ BsmtCond     : chr  "TA" "TA" "TA" "Gd" ...
##  $ BsmtExposure : chr  "No" "Gd" "Mn" "No" ...
##  $ BsmtFinType1 : chr  "GLQ" "ALQ" "GLQ" "ALQ" ...
##  $ BsmtFinSF1   : int  706 978 486 216 655 732 1369 859 0 851 ...
##  $ BsmtFinType2 : chr  "Unf" "Unf" "Unf" "Unf" ...
##  $ BsmtFinSF2   : int  0 0 0 0 0 0 0 32 0 0 ...
##  $ BsmtUnfSF    : int  150 284 434 540 490 64 317 216 952 140 ...
##  $ TotalBsmtSF  : int  856 1262 920 756 1145 796 1686 1107 952 991 ...
##  $ Heating      : chr  "GasA" "GasA" "GasA" "GasA" ...
##  $ HeatingQC    : chr  "Ex" "Ex" "Ex" "Gd" ...
##  $ CentralAir   : chr  "Y" "Y" "Y" "Y" ...
##  $ Electrical   : chr  "SBrkr" "SBrkr" "SBrkr" "SBrkr" ...
##  $ X1stFlrSF    : int  856 1262 920 961 1145 796 1694 1107 1022 1077 ...
##  $ X2ndFlrSF    : int  854 0 866 756 1053 566 0 983 752 0 ...
##  $ LowQualFinSF : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ GrLivArea    : int  1710 1262 1786 1717 2198 1362 1694 2090 1774 1077 ...
##  $ BsmtFullBath : int  1 0 1 1 1 1 1 1 0 1 ...
##  $ BsmtHalfBath : int  0 1 0 0 0 0 0 0 0 0 ...
##  $ FullBath     : int  2 2 2 1 2 1 2 2 2 1 ...
```

```
##  $ HalfBath     : int  1 0 1 0 1 1 0 1 0 0 ...
##  $ BedroomAbvGr : int  3 3 3 3 4 1 3 3 2 2 ...
##  $ KitchenAbvGr : int  1 1 1 1 1 1 1 1 2 2 ...
##  $ KitchenQual  : chr  "Gd" "TA" "Gd" "Gd" ...
##  $ TotRmsAbvGrd : int  8 6 6 7 9 5 7 7 8 5 ...
##  $ Functional   : chr  "Typ" "Typ" "Typ" "Typ" ...
##  $ Fireplaces   : int  0 1 1 1 1 0 1 2 2 2 ...
##  $ FireplaceQu  : chr  NA "TA" "TA" "Gd" ...
##  $ GarageType   : chr  "Attchd" "Attchd" "Attchd" "Detchd" ...
##  $ GarageYrBlt  : int  2003 1976 2001 1998 2000 1993 2004 1973 1931 1939 ...
##  $ GarageFinish : chr  "RFn" "RFn" "RFn" "Unf" ...
##  $ GarageCars   : int  2 2 2 3 3 2 2 2 2 1 ...
##  $ GarageArea   : int  548 460 608 642 836 480 636 484 468 205 ...
##  $ GarageQual   : chr  "TA" "TA" "TA" "TA" ...
##  $ GarageCond   : chr  "TA" "TA" "TA" "TA" ...
##  $ PavedDrive   : chr  "Y" "Y" "Y" "Y" ...
##  $ WoodDeckSF   : int  0 298 0 0 192 40 255 235 90 0 ...
##  $ OpenPorchSF  : int  61 0 42 35 84 30 57 204 0 4 ...
##  $ EnclosedPorch: int  0 0 0 272 0 0 0 228 205 0 ...
##  $ X3SsnPorch   : int  0 0 0 0 0 320 0 0 0 0 ...
##  $ ScreenPorch  : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ PoolArea     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ PoolQC       : chr  NA NA NA NA ...
##  $ Fence        : chr  NA NA NA NA ...
##  $ MiscFeature  : chr  NA NA NA NA ...
##  $ MiscVal      : int  0 0 0 0 0 700 0 350 0 0 ...
##  $ MoSold       : int  2 5 9 2 12 10 8 11 4 1 ...
##  $ YrSold       : int  2008 2007 2008 2006 2008 2009 2007 2009 2008 2008 ...
##  $ SaleType     : chr  "WD" "WD" "WD" "WD" ...
##  $ SaleCondition: chr  "Normal" "Normal" "Normal" "Abnorml" ...
##  $ SalePrice    : int  208500 181500 223500 140000 250000 143000 307000 200000 129900 118000 ...
```

While the full variable descriptions can be found in the data_description.txt file in the repository, we have included a summary below:

MSSubClass: type of house, categorical

MSZoning: zone of house, categorical

LotFrontage: Linear feet of street connected to house, continuous

LotArea: Lot size in square feet, continuous

Street: Type of road access to house, categorical

Alley: Type of alley access to house, categorical

LotShape: General shape of property, categorical

LandContour: Flatness of the property, categorical

Utilities: Type of utilities available, categorical

LotConfig: Type of lot, categorical

LandSlope: Slope of property, categorical

Neighborhood: Physical location, categorical

Condition1: Proximity to various conditions, categorical

Condition2: Proximity to various conditions (if more than one is present), categorical

BldgType: Type of home, categorical

HouseStyle: Style of home, categorical

OverallQual: Rating of the overall material and finish of the house, categorical

OverallCond: Rating of the overall condition of the house, categorical

YearBuilt: Original construction date, continuous

YearRemodAdd: Remodel date (same as construction date if no remodeling or additions), continuous

RoofStyle: Type of roof, categorical

RoofMatl: Roof material, categorical

Exterior1st: Exterior covering on house, categorical

Exterior2nd: Exterior covering on house (if more than one material), categorical

MasVnrType: Masonry veneer type, categorical

MasVnrArea: Masonry veneer area in square feet, categorical

ExterQual: Evaluates the quality of the material on the exterior, categorical

ExterCond: Evaluates the present condition of the material on the exterior, categorical

Foundation: Type of foundation, categorical

BsmtQual: Evaluates the height of the basement, categorical

BsmtCond: Evaluates the general condition of the basement, categorical

BsmtExposure: Refers to walkout or garden level walls, categorical

BsmtFinType1: Rating of basement finished area, categorical

BsmtFinSF1: Type 1 finished square feet, continuous

BsmtFinType2: Rating of basement finished area (if multiple types), categorical

BsmtFinSF2: Type 2 finished square feet, continuous

BsmtUnfSF: Unfinished square feet of basement area, continuous

TotalBsmtSF: Total square feet of basement area, continuous

Heating: Type of heating, categorical

HeatingQC: Heating quality and condition, categorical

CentralAir: Central air conditioning, categorical (binary)

Electrical: Electrical system, categorical

1stFlrSF: First Floor square feet, continuous

2ndFlrSF: Second floor square feet, continuous

LowQualFinSF: Low quality finished square feet (all floors), continuous

GrLivArea: Above ground living area square feet, continuous

BsmtFullBath: Basement full bathrooms, continuous

BsmtHalfBath: Basement half bathrooms, continuous

FullBath: Full bathrooms above ground, continuous

HalfBath: Half baths above ground, continuous

Bedroom: Bedrooms above ground (does NOT include basement bedrooms), continuous

Kitchen: Kitchens above grade, continuous

KitchenQual: Kitchen quality, categorical

TotRmsAbvGrd: Total rooms above ground (does not include bathrooms), continuous

Functional: Home functionality, categorical

Fireplaces: Number of fireplaces, continuous

FireplaceQu: Fireplace quality, categorical

GarageType: Garage location, categorical

GarageYrBlt: Year garage was built, continuous

GarageFinish: Interior finish of the garage, categorical

GarageCars: Size of garage in car capacity, continuous

GarageArea: Size of garage in square feet, continuous

GarageQual: Garage quality, categorical

GarageCond: Garage condition, categorical

PavedDrive: Paved driveway, categorical

WoodDeckSF: Wood deck area in square feet, continuous

OpenPorchSF: Open porch area in square feet, continuous

EnclosedPorch: Enclosed porch area in square feet, continuous

3SsnPorch: Three season porch area in square feet, continuous

ScreenPorch: Screen porch area in square feet, continuous

PoolArea: Pool area in square feet, continuous

PoolQC: Pool quality, categorical

Fence: Fence quality, categorical

MiscFeature: Miscellaneous feature not covered in other categories, categorical

MiscVal: Value of miscellaneous feature, continuous

MoSold: Month Sold (MM), continuous

YrSold: Year Sold (YYYY), continuous

SaleType: Type of sale, categorical

SaleCondition: Condition of sale, categorical

SalePrice: Price the house was sold for, continuous

Although some of the variables were automatically mistyped by R, we don't need all the variables for our analysis. We will first drop some variables to reduce the dataset to the data required, then retype the variables as needed.

```
dat <- subset(dat, select=-c(Condition1, Condition2, Exterior2nd, MasVnrType, MasVnrArea, BsmtExposure,
dim(dat)
```

```
## [1] 1460   69
```

We are left with 69 features out of the original 81. We still have 1460 records, however, it is highly likely at least some of these have null values. We will examine these and clean them up next.

```
colSums(is.na(dat))
```

```
##    MSSubClass      MSZoning   LotFrontage       LotArea        Street
##             0             0           259             0             0
##         Alley      LotShape   LandContour     Utilities     LotConfig
##          1369             0             0             0             0
##     LandSlope  Neighborhood      BldgType    HouseStyle   OverallQual
##             0             0             0             0             0
##   OverallCond     YearBuilt  YearRemodAdd     RoofStyle      RoofMatl
##             0             0             0             0             0
##   Exterior1st     ExterQual     ExterCond    Foundation      BsmtQual
##             0             0             0             0            37
##      BsmtCond  BsmtFinType1    BsmtFinSF1     BsmtUnfSF   TotalBsmtSF
##            37            37             0             0             0
##       Heating     HeatingQC    CentralAir    Electrical     X1stFlrSF
##             0             0             0             1             0
##     X2ndFlrSF  LowQualFinSF     GrLivArea  BsmtFullBath  BsmtHalfBath
##             0             0             0             0             0
##      FullBath      HalfBath  BedroomAbvGr  KitchenAbvGr   KitchenQual
##             0             0             0             0             0
##  TotRmsAbvGrd    Functional    Fireplaces   FireplaceQu    GarageType
##             0             0             0           690            81
##  GarageFinish    GarageCars    GarageArea    GarageQual    GarageCond
##            81             0             0            81            81
##    PavedDrive    WoodDeckSF   OpenPorchSF EnclosedPorch    X3SsnPorch
##             0             0             0             0             0
##   ScreenPorch      PoolArea        PoolQC         Fence   MiscFeature
##             0             0          1453          1179          1406
##       MiscVal        MoSold        YrSold     SalePrice
##             0             0             0             0
```

```
dat$LotFrontage[is.na(dat$LotFrontage)] <- 0
dat$Alley[is.na(dat$Alley)] <- "None"
dat$BsmtQual[is.na(dat$BsmtQual)] <- "None"
dat$BsmtCond[is.na(dat$BsmtCond)] <- "None"
dat$BsmtFinType1[is.na(dat$BsmtFinType1)] <- "None"
dat$Electrical[is.na(dat$Electrical)] <- "Unknown"
dat$FireplaceQu[is.na(dat$FireplaceQu)] <- "None"
dat$GarageType[is.na(dat$GarageType)] <- "None"
dat$GarageFinish[is.na(dat$GarageFinish)] <- "None"
dat$GarageQual[is.na(dat$GarageQual)] <- "None"
dat$GarageCond[is.na(dat$GarageCond)] <- "None"
dat$PoolQC[is.na(dat$PoolQC)] <- "None"
dat$Fence[is.na(dat$Fence)] <- "None"
dat$MiscFeature[is.na(dat$MiscFeature)] <- "None"
```

Checking our work:

```
colSums(is.na(dat))
```

```
##    MSSubClass      MSZoning   LotFrontage       LotArea        Street
##             0             0             0             0             0
##         Alley      LotShape   LandContour     Utilities     LotConfig
##             0             0             0             0             0
##     LandSlope  Neighborhood      BldgType    HouseStyle   OverallQual
##             0             0             0             0             0
##   OverallCond     YearBuilt  YearRemodAdd     RoofStyle      RoofMatl
##             0             0             0             0             0
##   Exterior1st     ExterQual     ExterCond    Foundation      BsmtQual
##             0             0             0             0             0
##      BsmtCond  BsmtFinType1    BsmtFinSF1     BsmtUnfSF   TotalBsmtSF
##             0             0             0             0             0
##       Heating     HeatingQC    CentralAir    Electrical     X1stFlrSF
##             0             0             0             0             0
##     X2ndFlrSF  LowQualFinSF     GrLivArea  BsmtFullBath  BsmtHalfBath
##             0             0             0             0             0
##      FullBath      HalfBath  BedroomAbvGr  KitchenAbvGr   KitchenQual
##             0             0             0             0             0
##  TotRmsAbvGrd    Functional    Fireplaces   FireplaceQu    GarageType
##             0             0             0             0             0
##  GarageFinish    GarageCars    GarageArea    GarageQual    GarageCond
##             0             0             0             0             0
##    PavedDrive    WoodDeckSF   OpenPorchSF EnclosedPorch    X3SsnPorch
##             0             0             0             0             0
##   ScreenPorch      PoolArea        PoolQC         Fence   MiscFeature
##             0             0             0             0             0
##       MiscVal        MoSold        YrSold     SalePrice
##             0             0             0             0
```

Now that we have removed all the nulls, we will retype our variables.

```
dat$MSSubClass <- as.factor(dat$MSSubClass)
dat$MSZoning <- as.factor(dat$MSZoning)
dat$Street <- as.factor(dat$Street)
dat$Alley <- as.factor(dat$Alley)
dat$LotShape <- as.factor(dat$LotShape)
dat$LandContour <- as.factor(dat$LandContour)
dat$Utilities <- as.factor(dat$Utilities)
dat$LotConfig <- as.factor(dat$LotConfig)
dat$LandSlope <- as.factor(dat$LandSlope)
dat$Neighborhood <- as.factor(dat$Neighborhood)
dat$BldgType <- as.factor(dat$BldgType)
dat$HouseStyle <- as.factor(dat$HouseStyle)
dat$OverallQual <- as.factor(dat$OverallQual)
dat$OverallCond <- as.factor(dat$OverallCond)
dat$RoofStyle <- as.factor(dat$RoofStyle)
dat$RoofMatl <- as.factor(dat$RoofMatl)
dat$Exterior1st <- as.factor(dat$Exterior1st)
dat$ExterQual <- as.factor(dat$ExterQual)
dat$ExterCond <- as.factor(dat$ExterCond)
dat$Foundation <- as.factor(dat$Foundation)
```

```
dat$BsmtQual <- as.factor(dat$BsmtQual)
dat$BsmtCond <- as.factor(dat$BsmtCond)
dat$BsmtFinType1 <- as.factor(dat$BsmtFinType1)
dat$Heating <- as.factor(dat$Heating)
dat$HeatingQC <- as.factor(dat$HeatingQC)
dat$CentralAir <- as.factor(dat$CentralAir)
dat$Electrical <- as.factor(dat$Electrical)
dat$KitchenQual <- as.factor(dat$KitchenQual)
dat$Functional <- as.factor(dat$Functional)
dat$FireplaceQu <- as.factor(dat$FireplaceQu)
dat$GarageType <- as.factor(dat$GarageType)
dat$GarageFinish <- as.factor(dat$GarageFinish)
dat$GarageQual <- as.factor(dat$GarageQual)
dat$GarageCond <- as.factor(dat$GarageCond)
dat$PavedDrive <- as.factor(dat$PavedDrive)
dat$PoolQC <- as.factor(dat$PoolQC)
dat$Fence <- as.factor(dat$Fence)
dat$MiscFeature <- as.factor(dat$MiscFeature)
```

Checking our work:

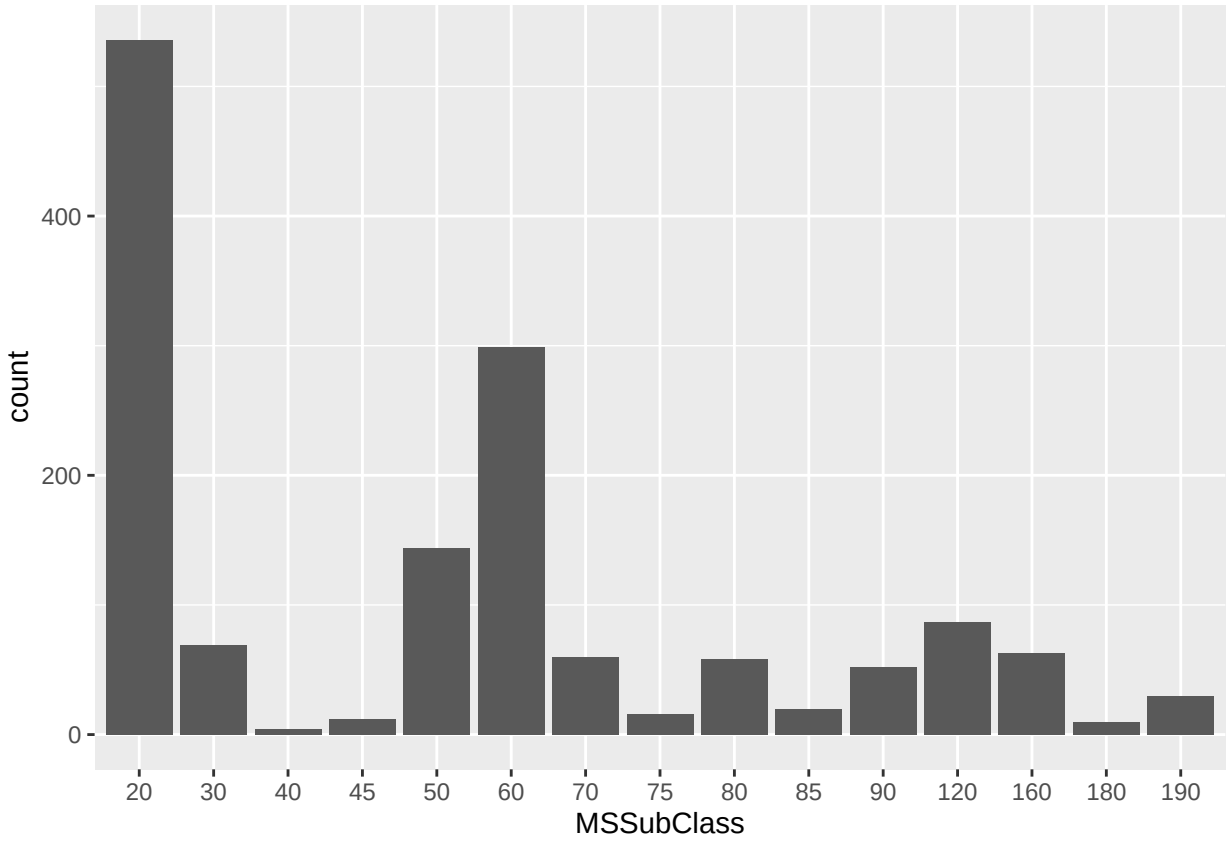
```
str(dat)
```

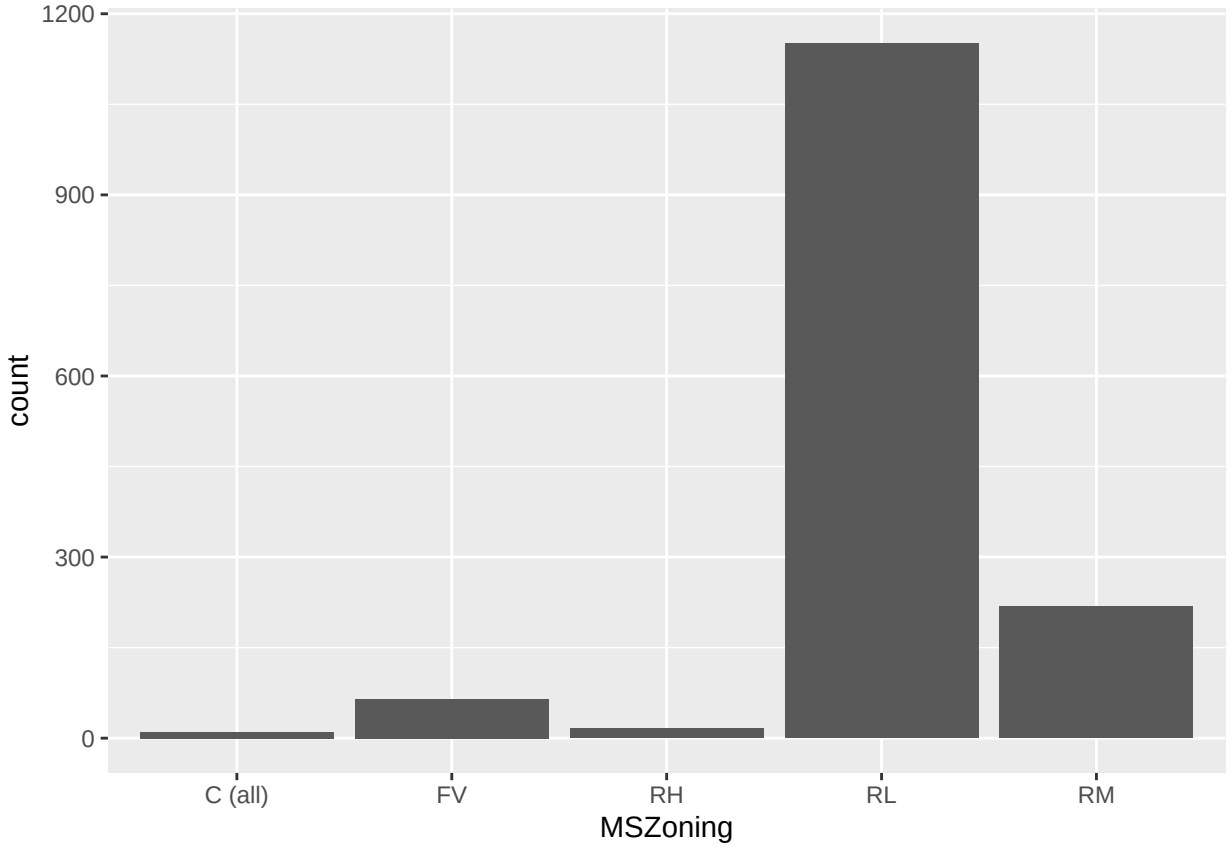
```
## 'data.frame':    1460 obs. of  69 variables:
##  $ MSSubClass   : Factor w/ 15 levels "20","30","40",..: 6 1 6 7 6 5 1 6 5 15 ...
##  $ MSZoning     : Factor w/ 5 levels "C (all)","FV",..: 4 4 4 4 4 4 4 4 5 4 ...
##  $ LotFrontage  : num  65 80 68 60 84 85 75 0 51 50 ...
##  $ LotArea      : int  8450 9600 11250 9550 14260 14115 10084 10382 6120 7420 ...
##  $ Street       : Factor w/ 2 levels "Grvl","Pave": 2 2 2 2 2 2 2 2 2 2 ...
##  $ Alley        : Factor w/ 3 levels "Grvl","None",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ LotShape     : Factor w/ 4 levels "IR1","IR2","IR3",..: 4 4 1 1 1 1 4 1 4 4 ...
##  $ LandContour  : Factor w/ 4 levels "Bnk","HLS","Low",..: 4 4 4 4 4 4 4 4 4 4 ...
##  $ Utilities    : Factor w/ 2 levels "AllPub","NoSeWa": 1 1 1 1 1 1 1 1 1 1 ...
##  $ LotConfig    : Factor w/ 5 levels "Corner","CulDSac",..: 5 3 5 1 3 5 5 1 5 1 ...
##  $ LandSlope    : Factor w/ 3 levels "Gtl","Mod","Sev": 1 1 1 1 1 1 1 1 1 1 ...
##  $ Neighborhood : Factor w/ 25 levels "Blmngtn","Blueste",..: 6 25 6 7 14 12 21 17 18 4 ...
##  $ BldgType     : Factor w/ 5 levels "1Fam","2fmCon",..: 1 1 1 1 1 1 1 1 1 2 ...
##  $ HouseStyle   : Factor w/ 8 levels "1.5Fin","1.5Unf",..: 6 3 6 6 6 1 3 6 1 2 ...
##  $ OverallQual  : Factor w/ 10 levels "1","2","3","4",..: 7 6 7 7 8 5 8 7 7 5 ...
##  $ OverallCond  : Factor w/ 9 levels "1","2","3","4",..: 5 8 5 5 5 5 5 6 5 6 ...
##  $ YearBuilt    : int  2003 1976 2001 1915 2000 1993 2004 1973 1931 1939 ...
##  $ YearRemodAdd : int  2003 1976 2002 1970 2000 1995 2005 1973 1950 1950 ...
##  $ RoofStyle    : Factor w/ 6 levels "Flat","Gable",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ RoofMatl     : Factor w/ 8 levels "ClyTile","CompShg",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ Exterior1st  : Factor w/ 15 levels "AsbShng","AsphShn",..: 13 9 13 14 13 13 13 7 4 9 ...
##  $ ExterQual    : Factor w/ 4 levels "Ex","Fa","Gd",..: 3 4 3 4 3 4 3 4 4 4 ...
##  $ ExterCond    : Factor w/ 5 levels "Ex","Fa","Gd",..: 5 5 5 5 5 5 5 5 5 5 ...
##  $ Foundation   : Factor w/ 6 levels "BrkTil","CBlock",..: 3 2 3 1 3 6 3 2 1 1 ...
##  $ BsmtQual     : Factor w/ 5 levels "Ex","Fa","Gd",..: 3 3 3 5 3 3 1 3 5 5 ...
##  $ BsmtCond     : Factor w/ 5 levels "Fa","Gd","None",..: 5 5 5 2 5 5 5 5 5 5 ...
##  $ BsmtFinType1 : Factor w/ 7 levels "ALQ","BLQ","GLQ",..: 3 1 3 1 3 3 3 1 7 3 ...
##  $ BsmtFinSF1   : int  706 978 486 216 655 732 1369 859 0 851 ...
##  $ BsmtUnfSF    : int  150 284 434 540 490 64 317 216 952 140 ...
```

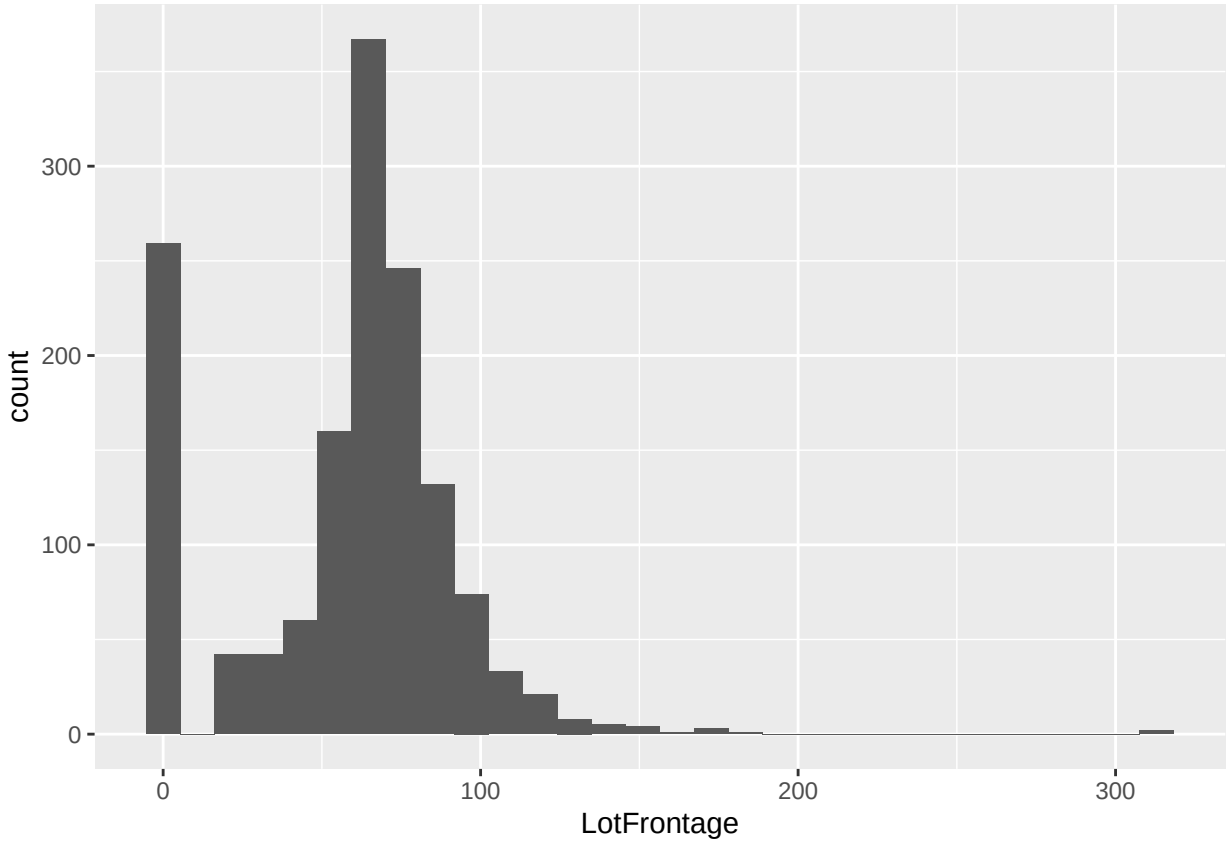
```
##  $ TotalBsmtSF  : int  856 1262 920 756 1145 796 1686 1107 952 991 ...
##  $ Heating      : Factor w/ 6 levels "Floor","GasA",..: 2 2 2 2 2 2 2 2 2 2 ...
##  $ HeatingQC    : Factor w/ 5 levels "Ex","Fa","Gd",..: 1 1 1 3 1 1 1 1 3 1 ...
##  $ CentralAir   : Factor w/ 2 levels "N","Y": 2 2 2 2 2 2 2 2 2 2 ...
##  $ Electrical   : Factor w/ 6 levels "FuseA","FuseF",..: 5 5 5 5 5 5 5 5 2 5 ...
##  $ X1stFlrSF    : int  856 1262 920 961 1145 796 1694 1107 1022 1077 ...
##  $ X2ndFlrSF    : int  854 0 866 756 1053 566 0 983 752 0 ...
##  $ LowQualFinSF : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ GrLivArea    : int  1710 1262 1786 1717 2198 1362 1694 2090 1774 1077 ...
##  $ BsmtFullBath : int  1 0 1 1 1 1 1 1 0 1 ...
##  $ BsmtHalfBath : int  0 1 0 0 0 0 0 0 0 0 ...
##  $ FullBath     : int  2 2 2 1 2 1 2 2 2 1 ...
##  $ HalfBath     : int  1 0 1 0 1 1 0 1 0 0 ...
##  $ BedroomAbvGr : int  3 3 3 3 4 1 3 3 2 2 ...
##  $ KitchenAbvGr : int  1 1 1 1 1 1 1 1 2 2 ...
##  $ KitchenQual  : Factor w/ 4 levels "Ex","Fa","Gd",..: 3 4 3 3 3 4 3 4 4 4 ...
##  $ TotRmsAbvGrd : int  8 6 6 7 9 5 7 7 8 5 ...
##  $ Functional   : Factor w/ 7 levels "Maj1","Maj2",..: 7 7 7 7 7 7 7 7 3 7 ...
##  $ Fireplaces   : int  0 1 1 1 1 0 1 2 2 2 ...
##  $ FireplaceQu  : Factor w/ 6 levels "Ex","Fa","Gd",..: 4 6 6 3 6 4 3 6 6 6 ...
##  $ GarageType   : Factor w/ 7 levels "2Types","Attchd",..: 2 2 2 6 2 2 2 2 6 2 ...
##  $ GarageFinish : Factor w/ 4 levels "Fin","None","RFn",..: 3 3 3 4 3 4 3 3 4 3 ...
##  $ GarageCars   : int  2 2 2 3 3 2 2 2 2 1 ...
##  $ GarageArea   : int  548 460 608 642 836 480 636 484 468 205 ...
##  $ GarageQual   : Factor w/ 6 levels "Ex","Fa","Gd",..: 6 6 6 6 6 6 6 6 2 3 ...
##  $ GarageCond   : Factor w/ 6 levels "Ex","Fa","Gd",..: 6 6 6 6 6 6 6 6 6 6 ...
##  $ PavedDrive   : Factor w/ 3 levels "N","P","Y": 3 3 3 3 3 3 3 3 3 3 ...
##  $ WoodDeckSF   : int  0 298 0 0 192 40 255 235 90 0 ...
##  $ OpenPorchSF  : int  61 0 42 35 84 30 57 204 0 4 ...
##  $ EnclosedPorch: int  0 0 0 272 0 0 0 228 205 0 ...
##  $ X3SsnPorch   : int  0 0 0 0 0 320 0 0 0 0 ...
##  $ ScreenPorch  : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ PoolArea     : int  0 0 0 0 0 0 0 0 0 0 ...
##  $ PoolQC       : Factor w/ 4 levels "Ex","Fa","Gd",..: 4 4 4 4 4 4 4 4 4 4 ...
##  $ Fence        : Factor w/ 5 levels "GdPrv","GdWo",..: 5 5 5 5 5 3 5 5 5 5 ...
##  $ MiscFeature  : Factor w/ 5 levels "Gar2","None",..: 2 2 2 2 2 4 2 4 2 2 ...
##  $ MiscVal      : int  0 0 0 0 0 700 0 350 0 0 ...
##  $ MoSold       : int  2 5 9 2 12 10 8 11 4 1 ...
##  $ YrSold       : int  2008 2007 2008 2006 2008 2009 2007 2009 2008 2008 ...
##  $ SalePrice    : int  208500 181500 223500 140000 250000 143000 307000 200000 129900 118000 ...
```

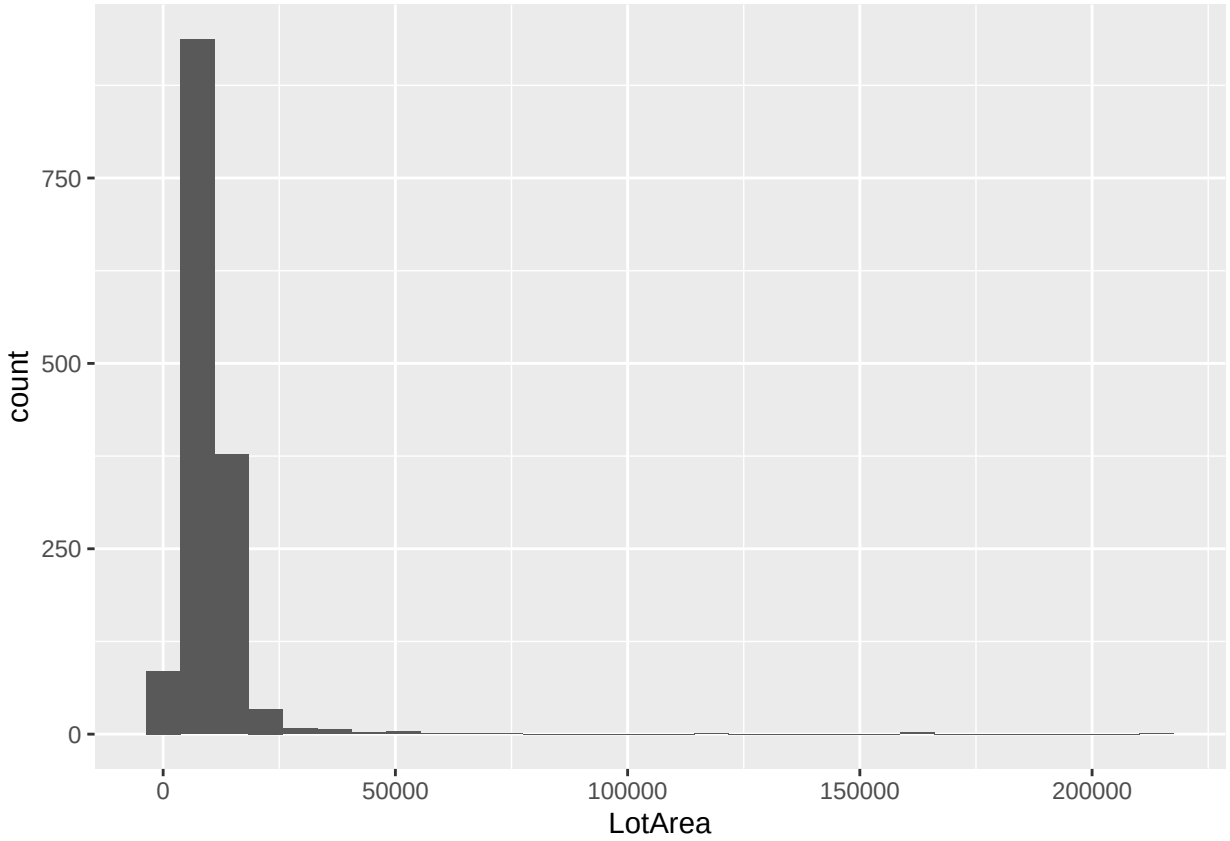
Exploratory Data Analysis

```
for (col in c(names(dat))) {
  g <- ggplot(data=dat, aes_string(x=col))
  if (is.numeric(dat[[col]])) {
    g <- g + geom_histogram(bins=30)
  } else {
    g <- g + geom_bar()
  }
  print(g)
}
```


count
400
200
0
20
30
40
45
50
60
70
75
80
85
90
120
160
180
190
MSSubClass


1200
900
600
300
0
count
C (all)
FV
RH
RL
RM
MSZoning


300
200
100
0
count
0
100
200
300
LotFrontage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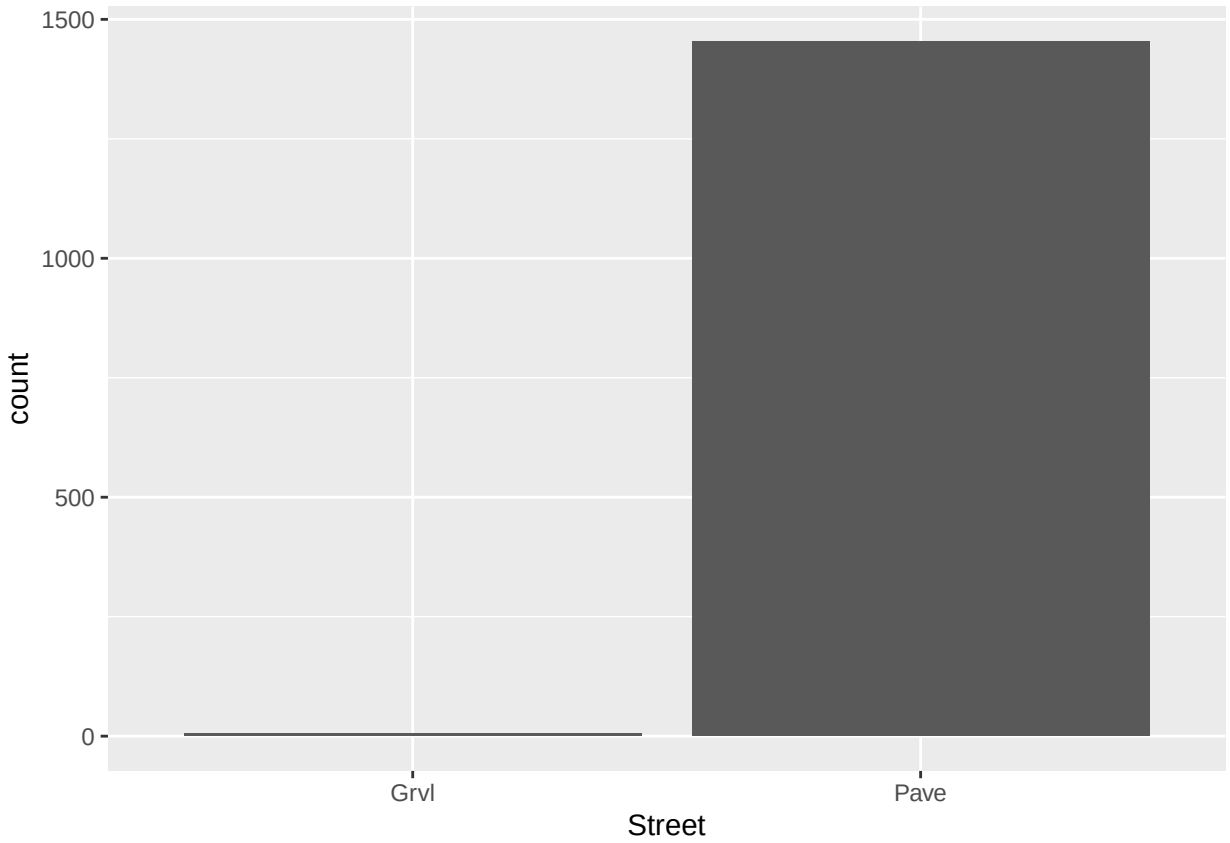
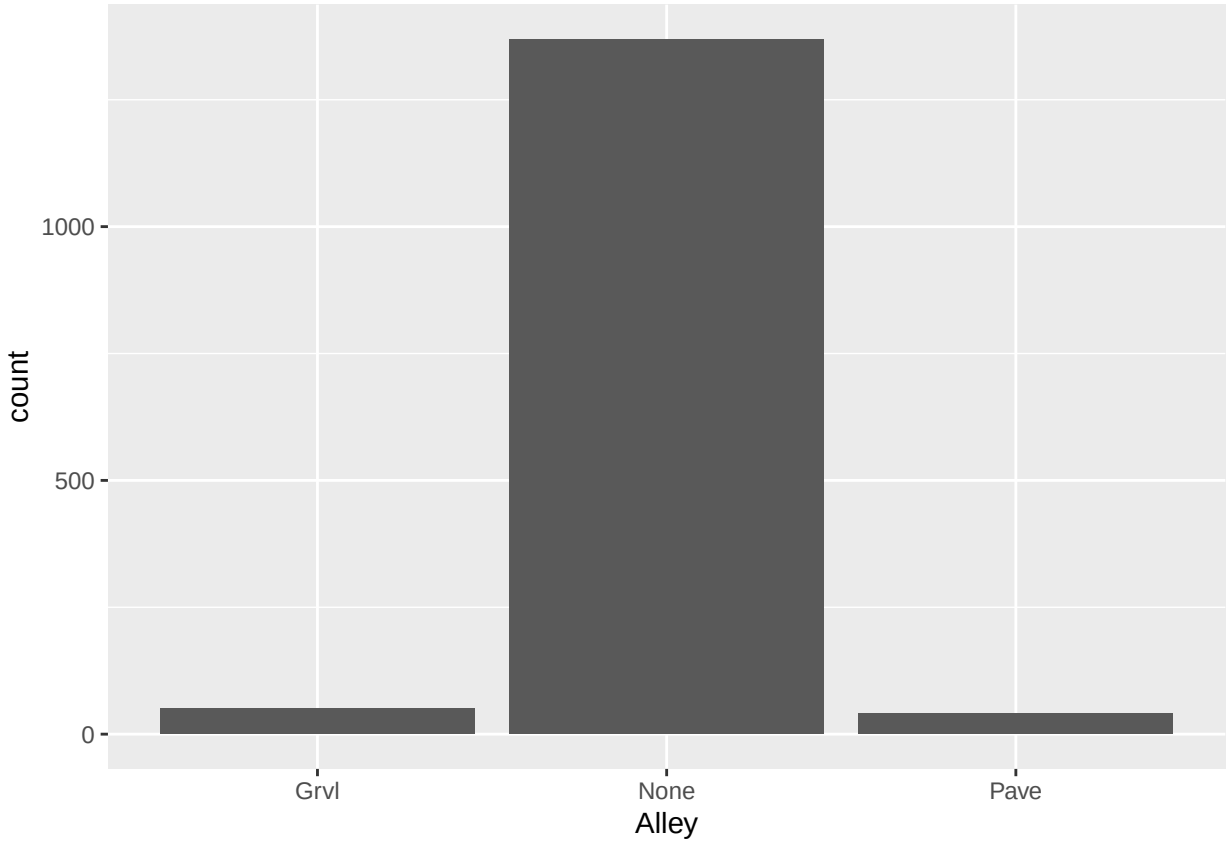
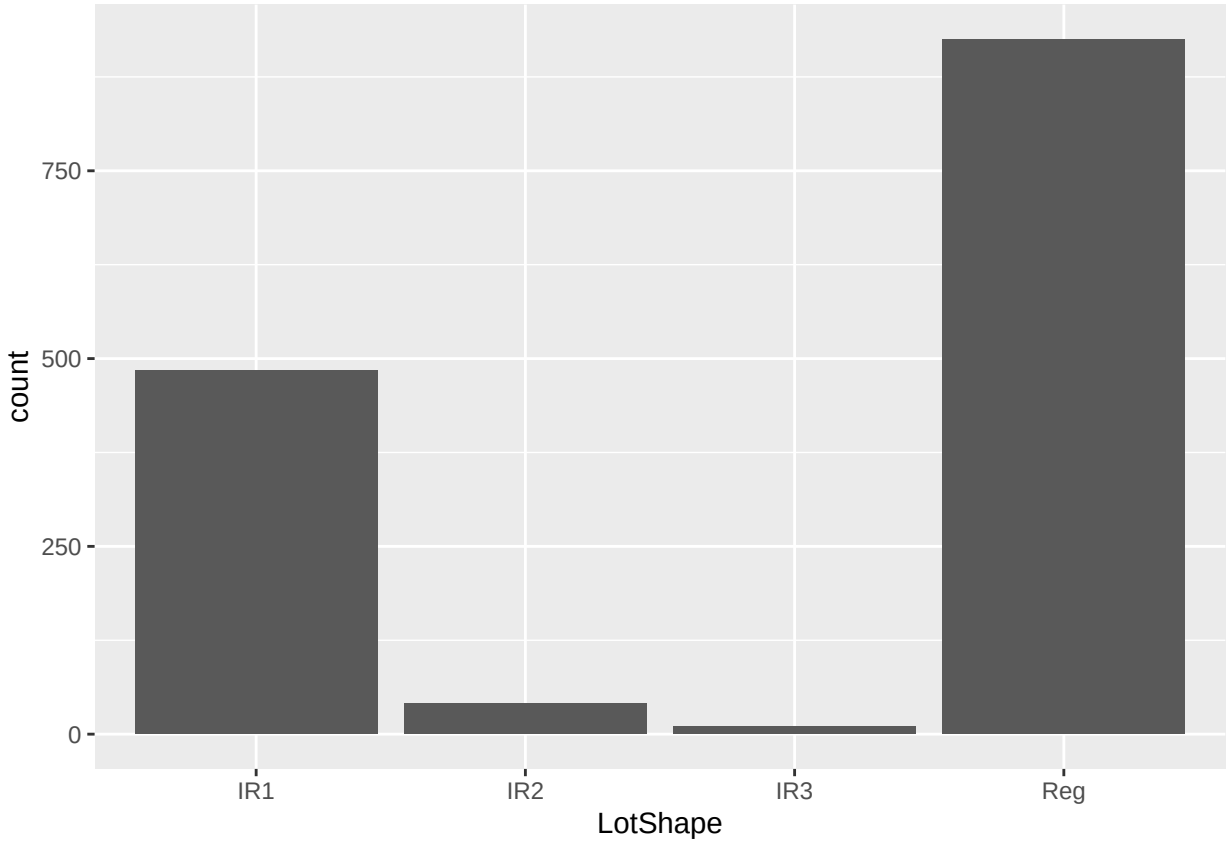
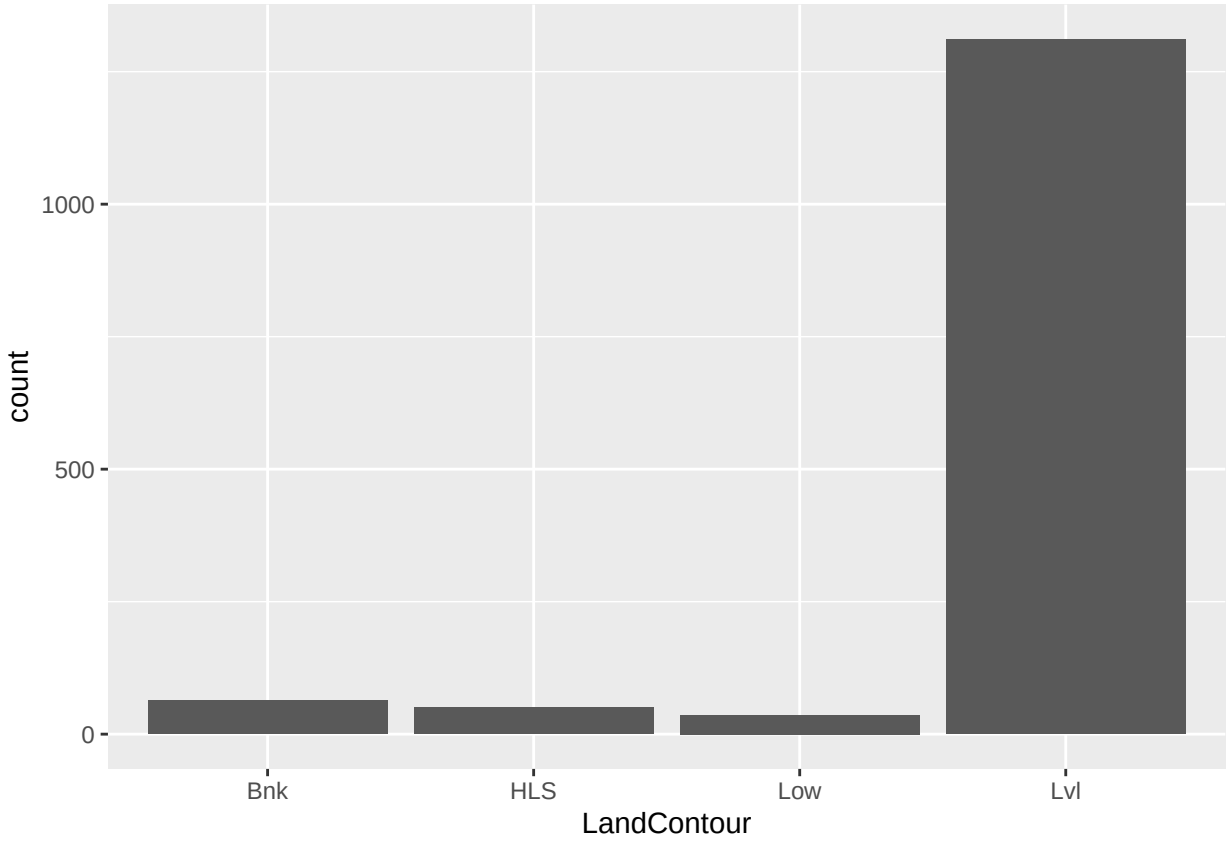
500
250
0
count
0
50000
100000
150000
200000
LotArea


1500
1000
500
0
count
Grvl
Pave
Street


1000
500
0
count
Grvl
None
Pave
Alley


750
500
250
0
count
IR1
IR2
IR3
Reg
LotShape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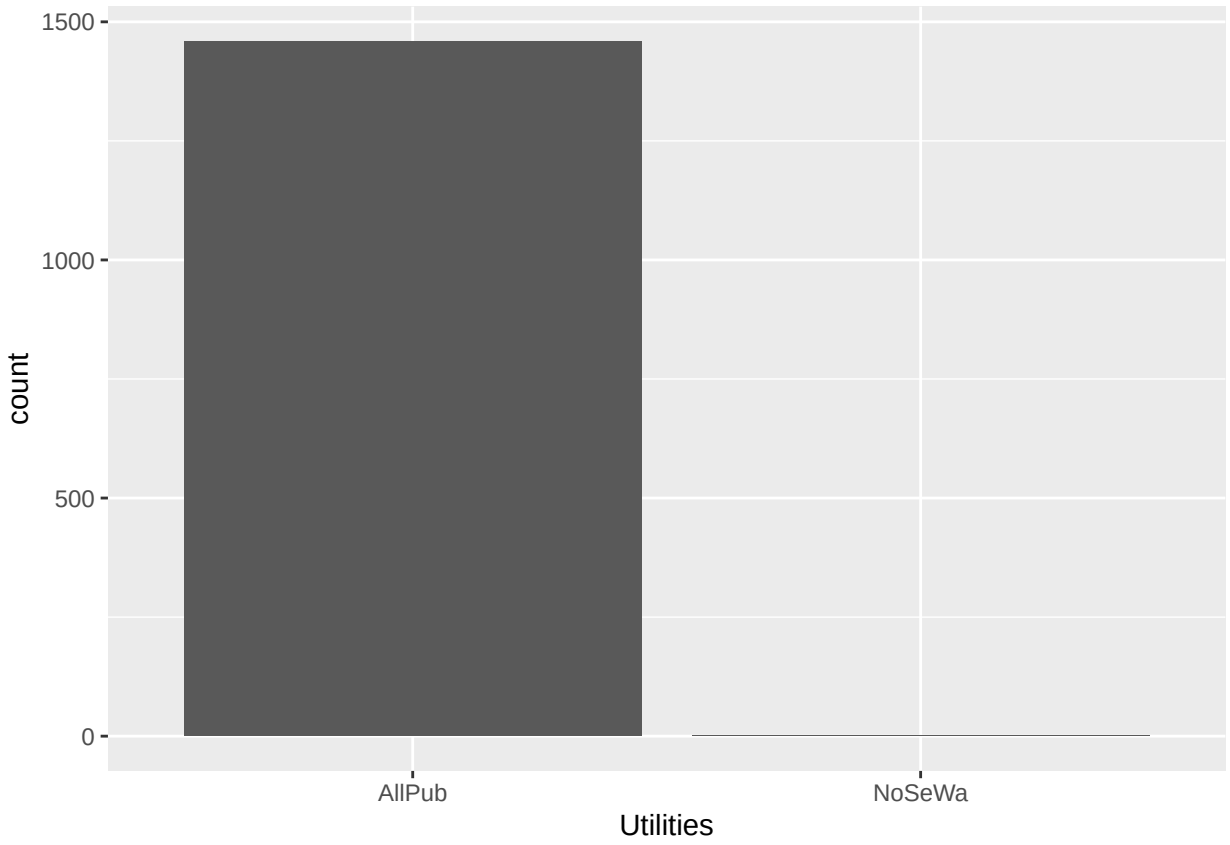
500
0
count
Bnk
HLS
Low
Lvl
LandContour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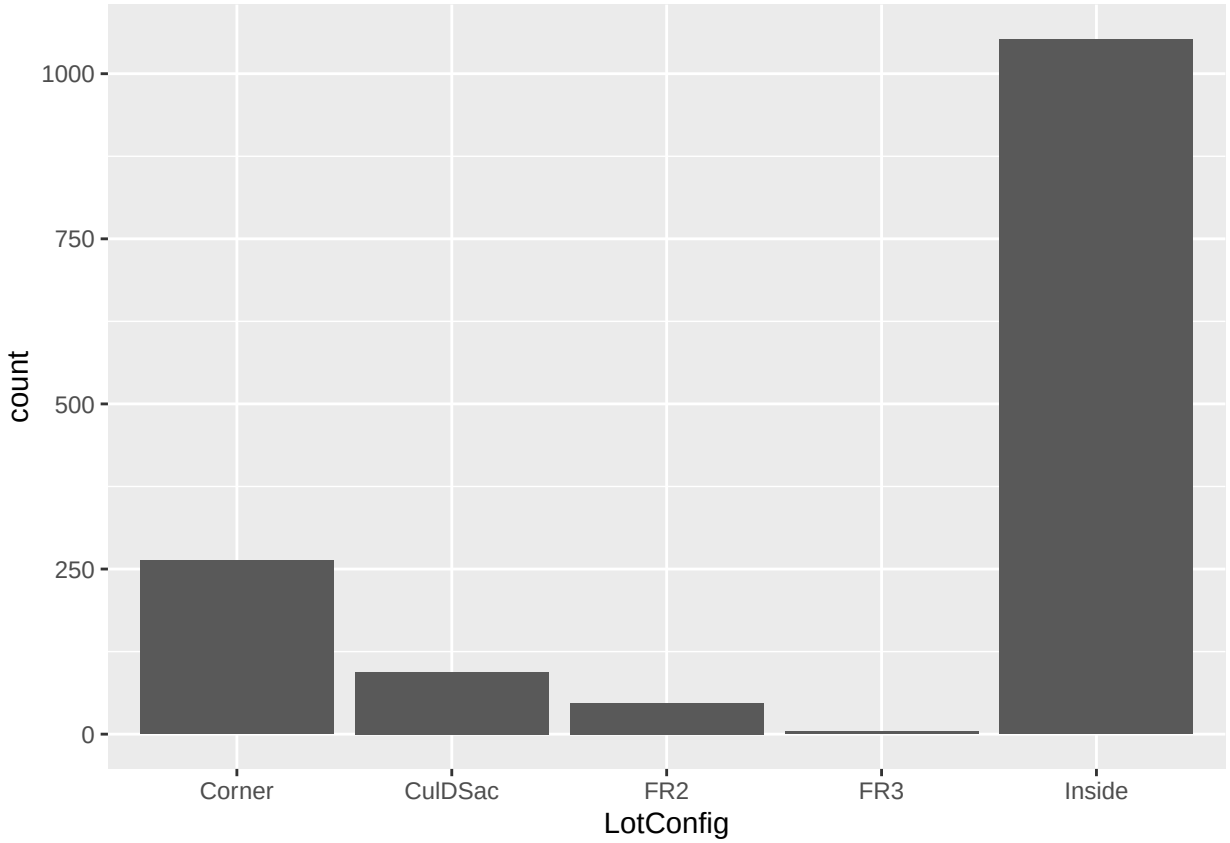
1000
500
0
count
AllPub
NoSeWa
Utilities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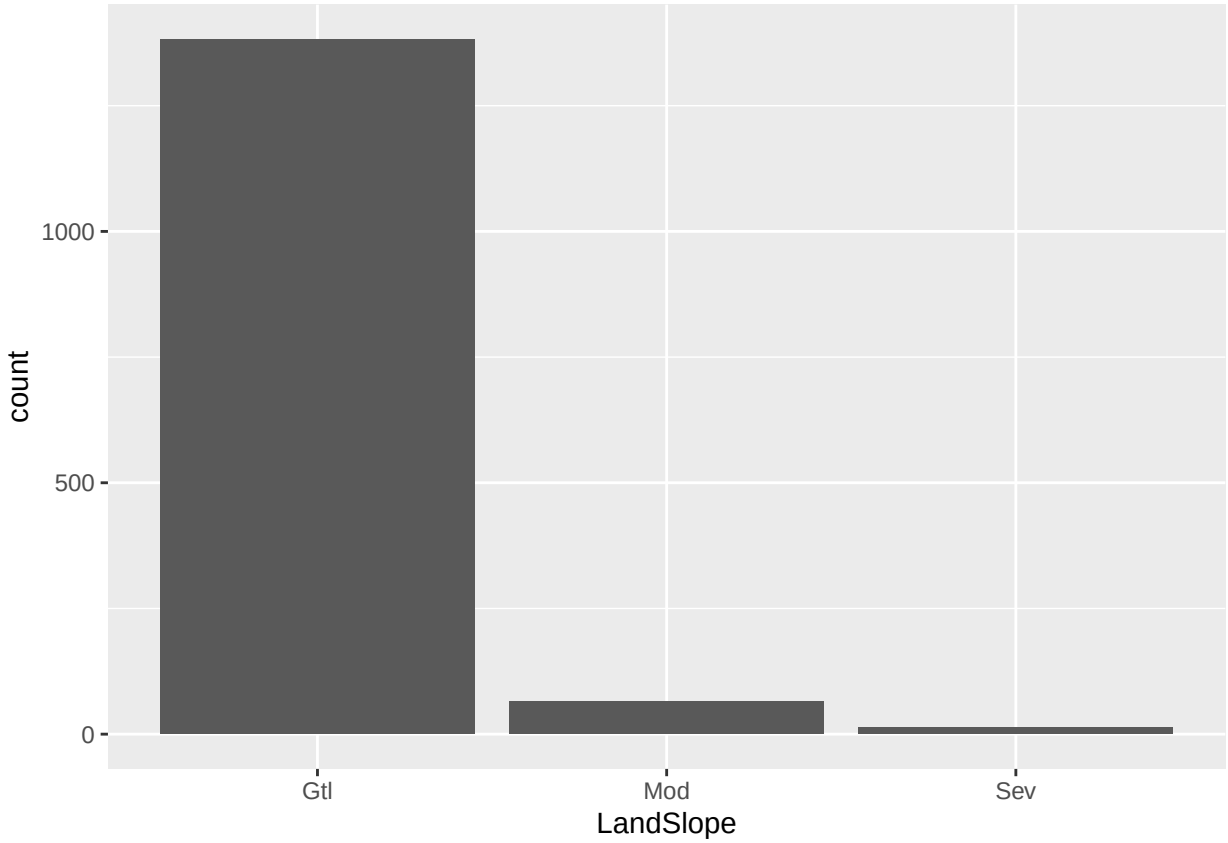
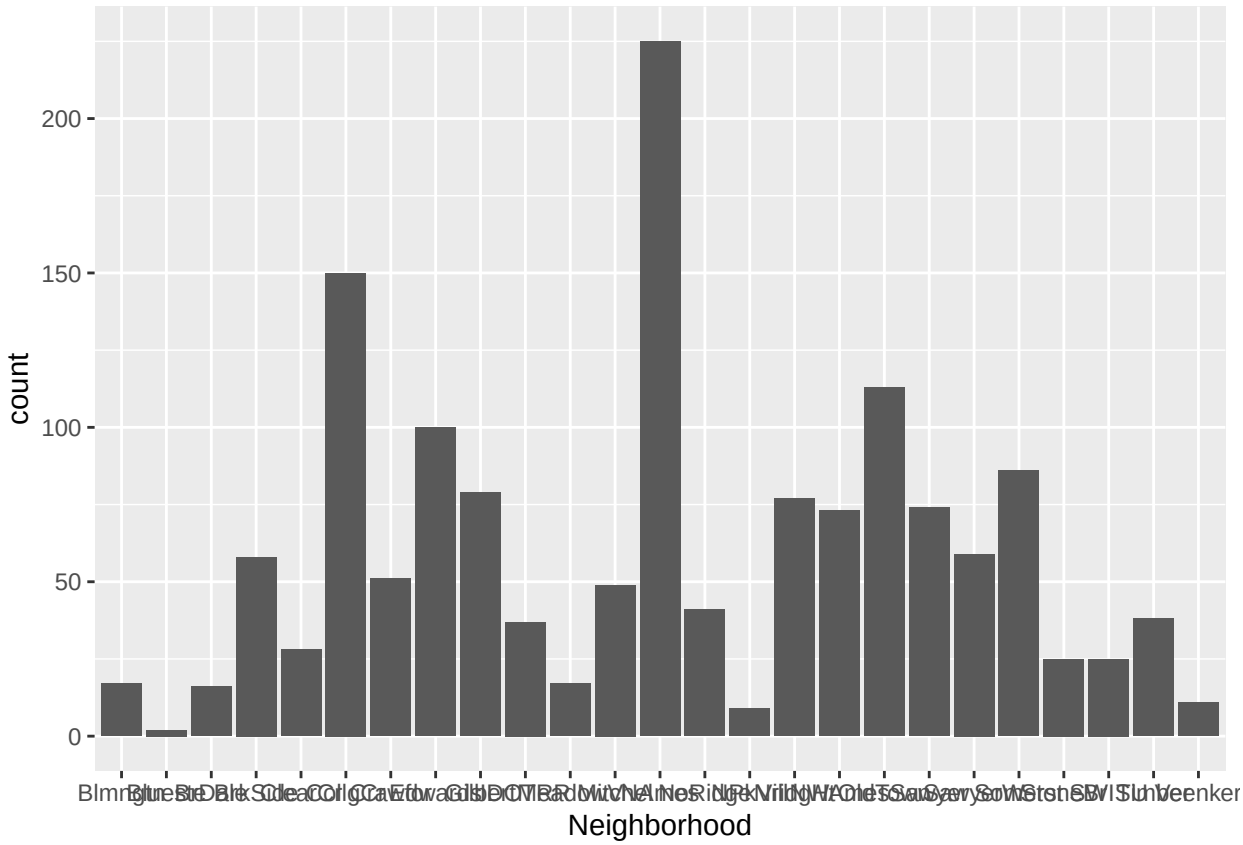
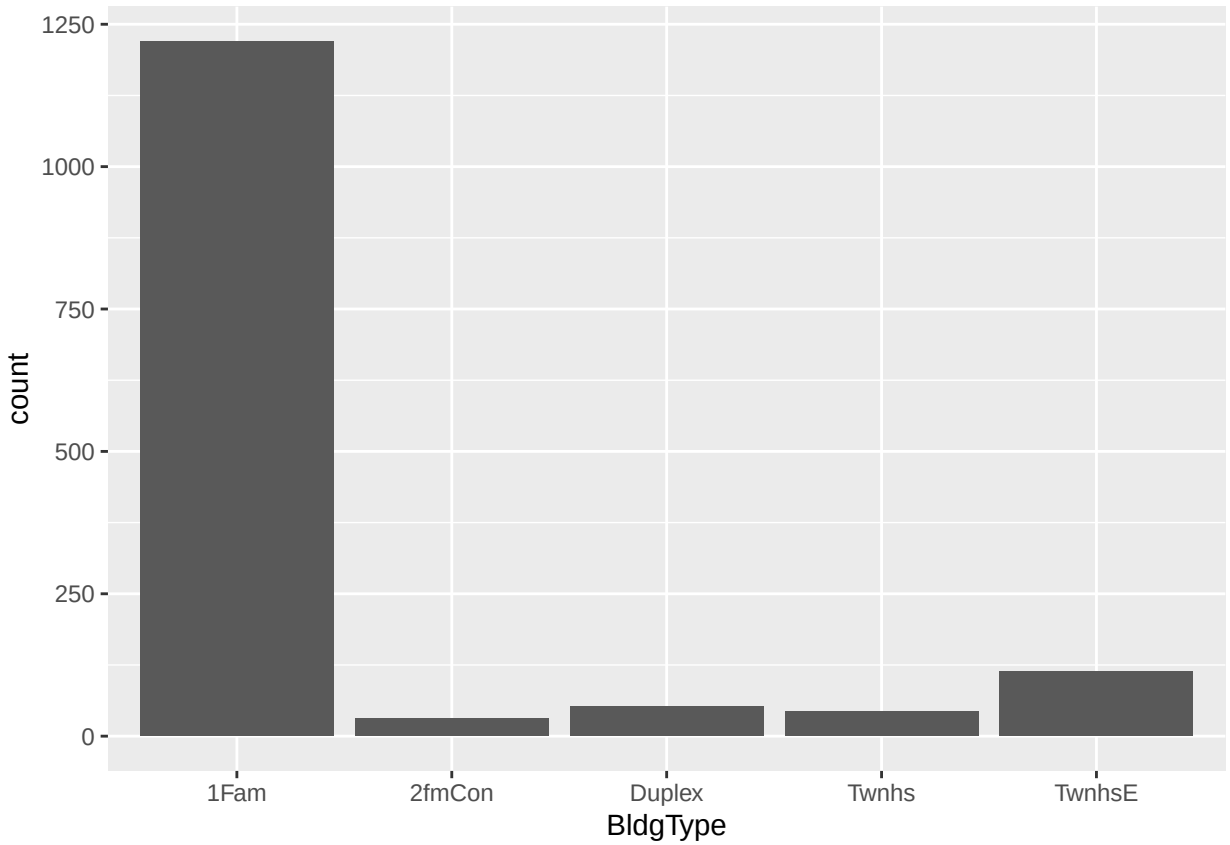
750
500
250
0
count
Corner
CulDSac
FR2
FR3
Inside
LotConfig


1000
500
0
count
Gtl
Mod
Sev
LandSlope


count
200
150
100
50
0
Neighborhood


1250
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750
500
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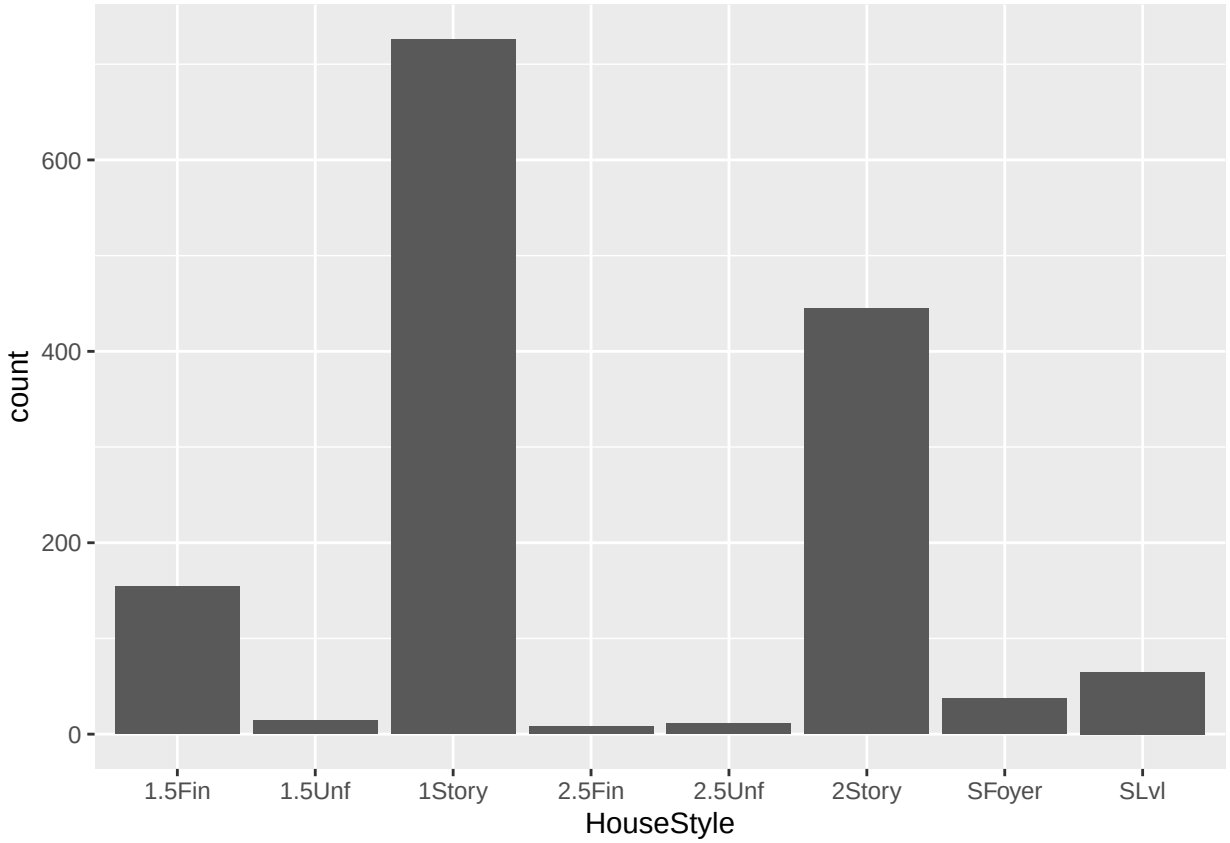
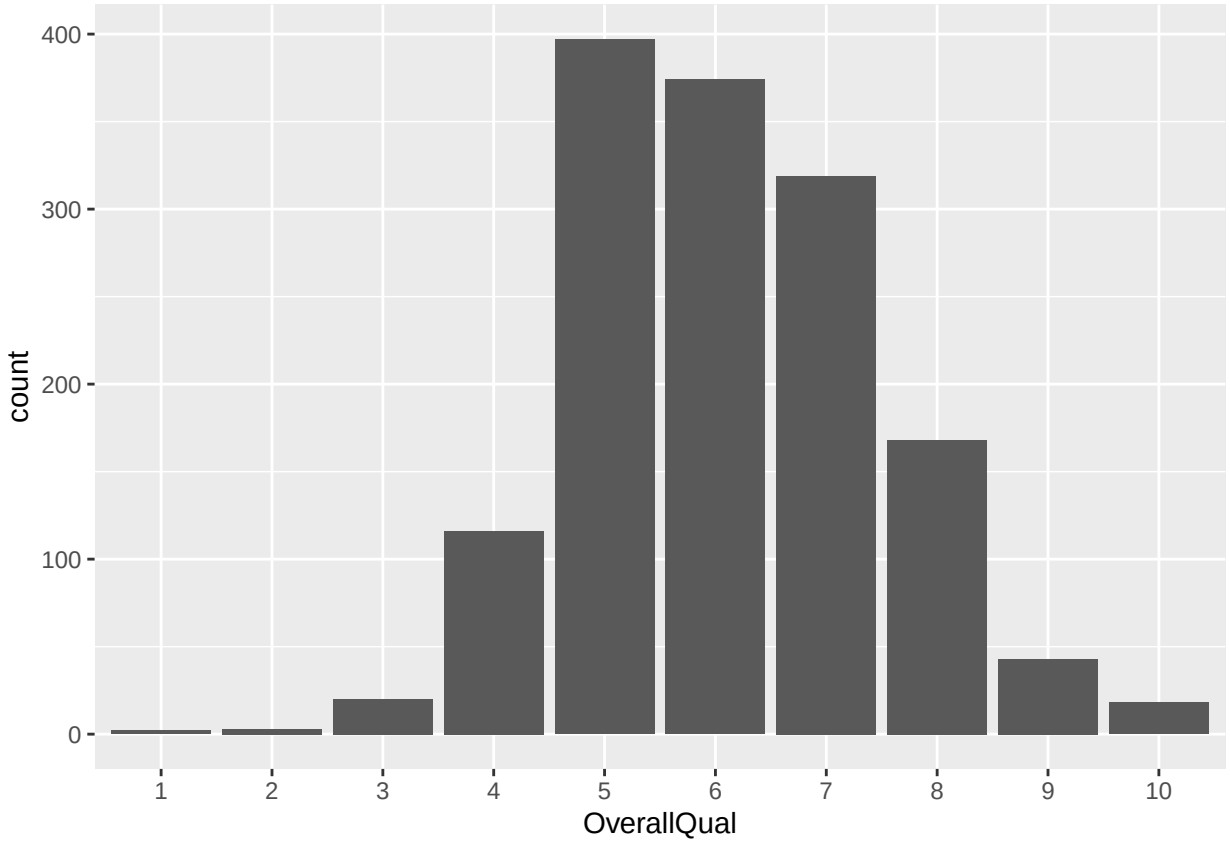
0
count
1Fam
2fmCon
Duplex
Twnhs
TwnhsE
BldgType


600
400
200
0
count
1.5Fin
1.5Unf
1Story
2.5Fin
2.5Unf
2Story
SFoyer
SLvl
HouseStyle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300
200
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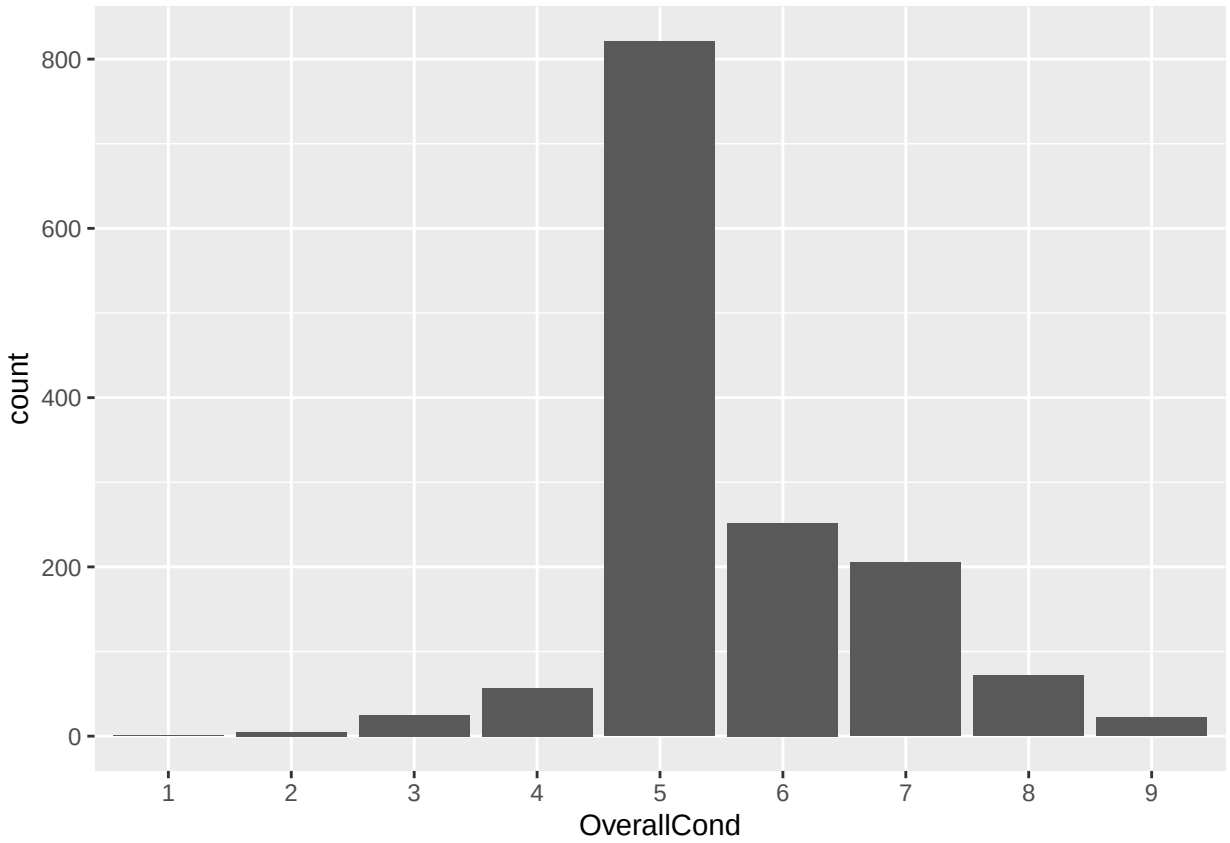
count
1
2
3
4
5
6
7
8
9
10
OverallQual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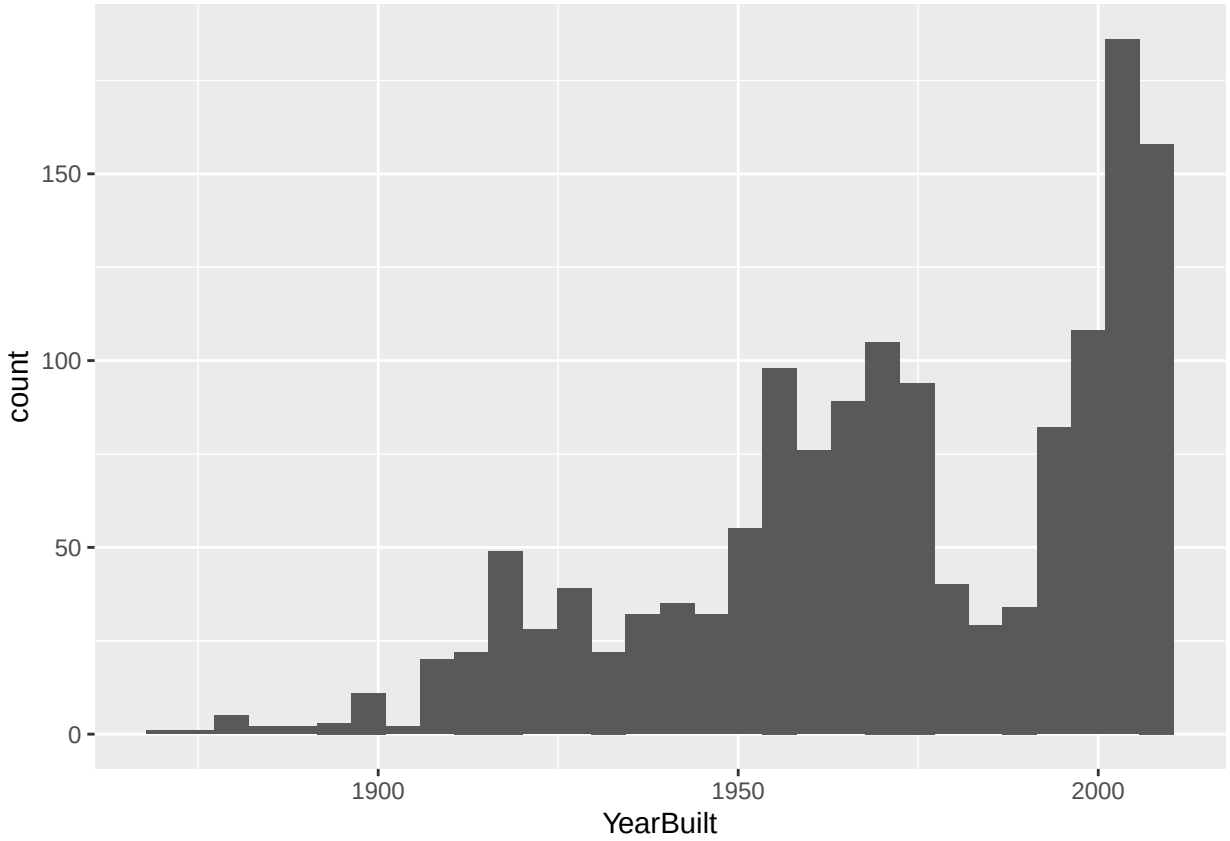
600
400
200
0
count
1
2
3
4
5
6
7
8
9
OverallCond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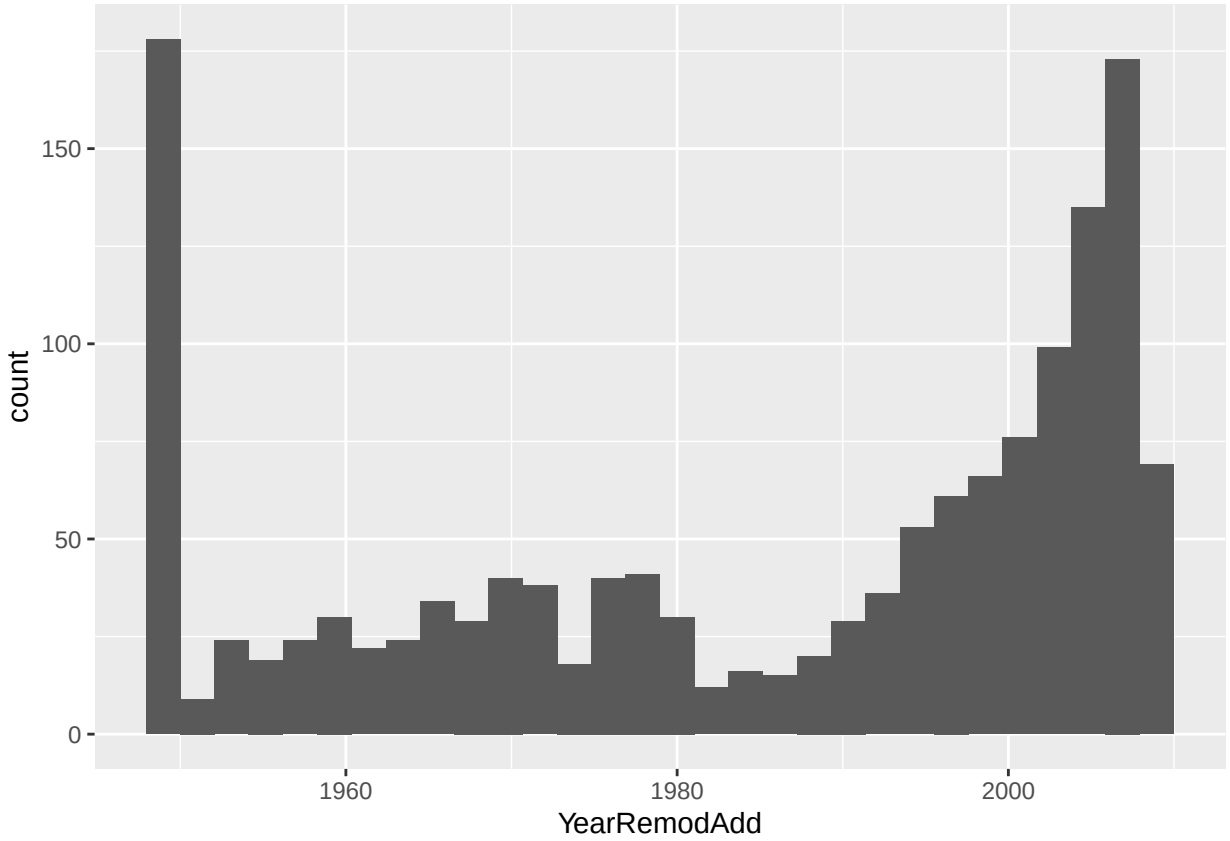
100
50
0
count
1900
1950
2000
YearBuilt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100
50
0
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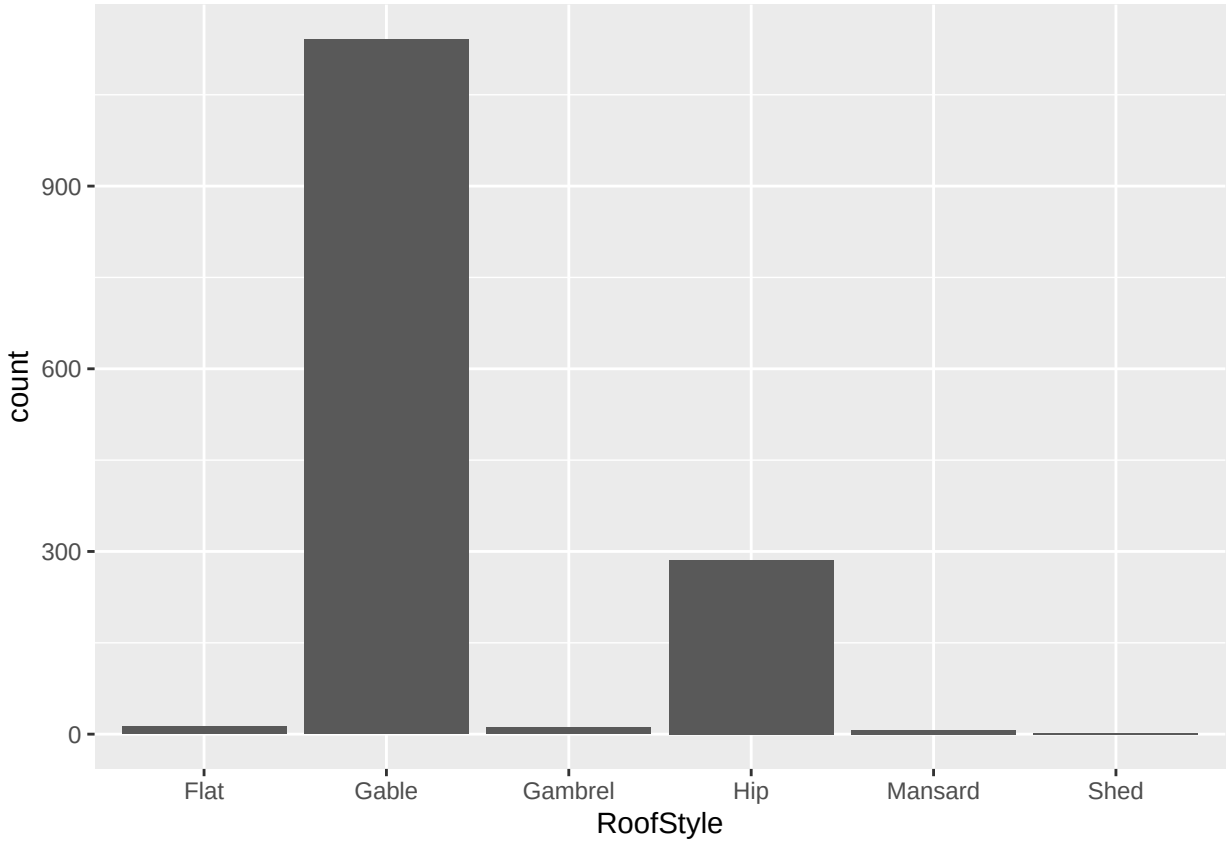
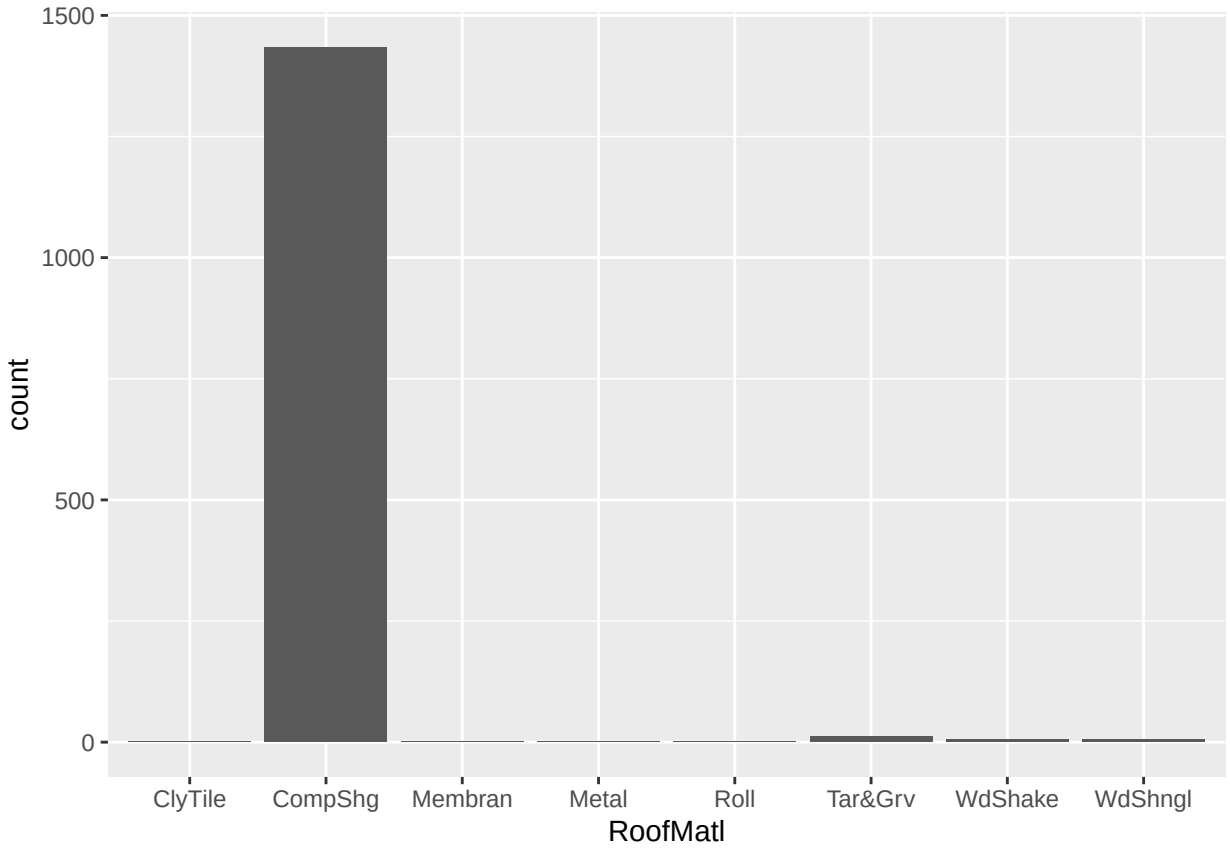
1960
1980
2000
YearRemodAdd


900
600
300
0
count
Flat
Gable
Gambrel
Hip
Mansard
Shed
RoofStyle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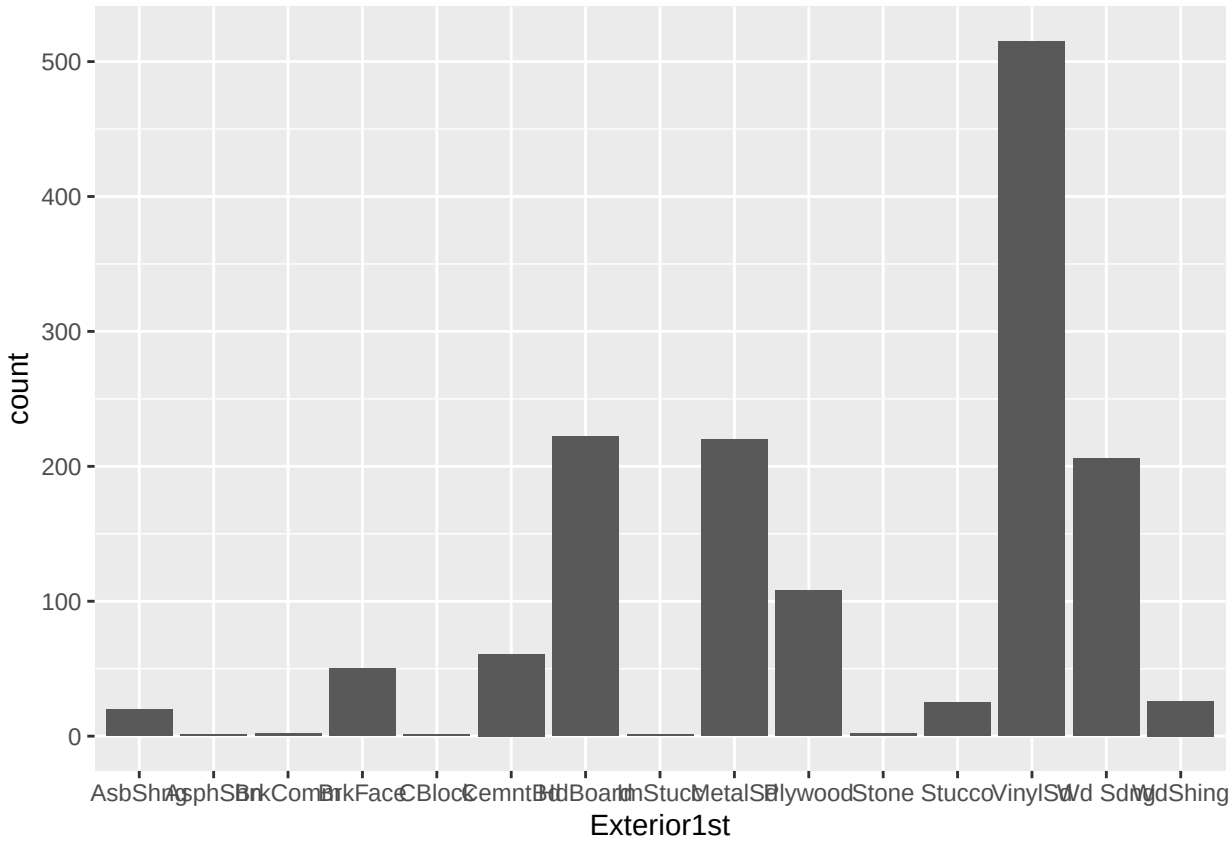
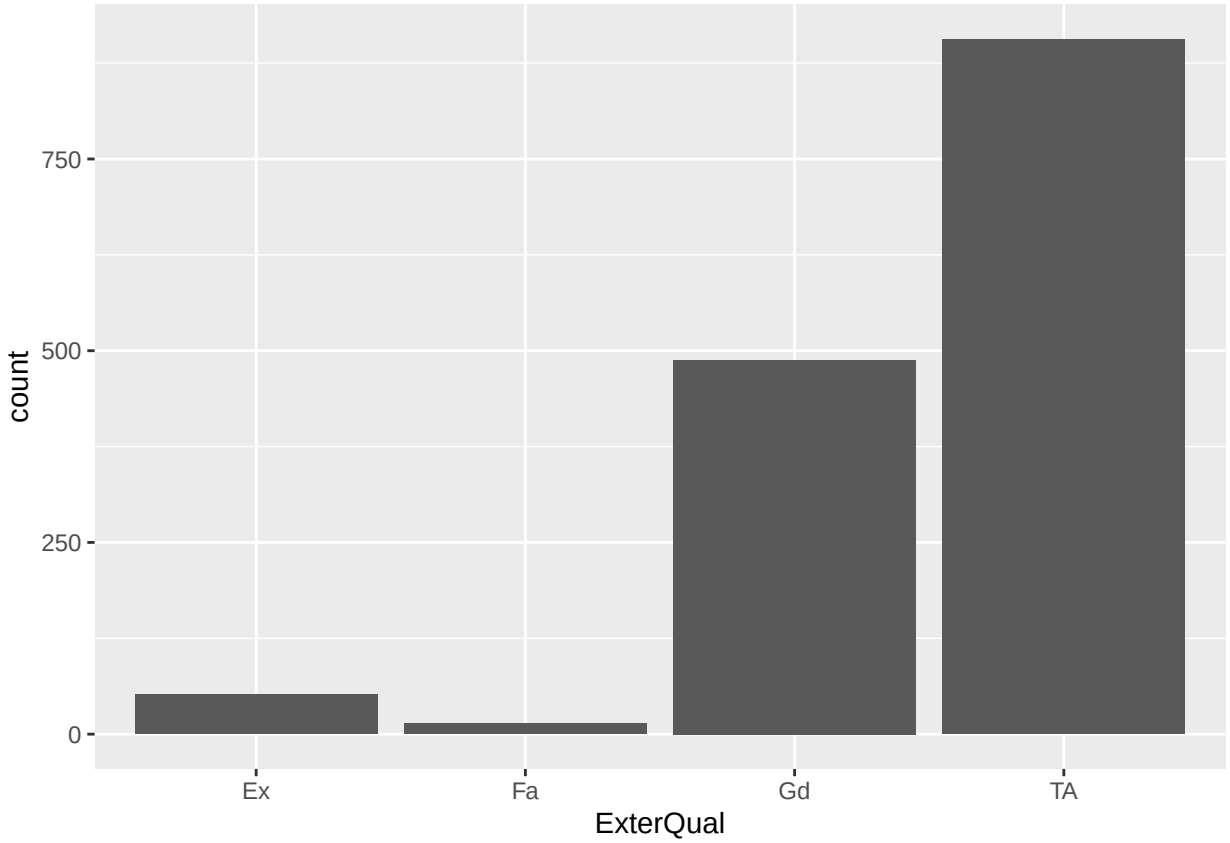
1000
500
0
count
ClyTile
CompShg
Membran
Metal
Roll
Tar&Grv
WdShake
WdShngl
RoofMatl


500
400
300
200
100
0
count
AsbShng
AsphShn
BrkComm
BrkFace
CBlock
CemntBd
HdBoard
ImStucc
MetalSd
Plywood
Stone
Stucco
VinylSd
Wd Sdng
WdShing
Exterior1st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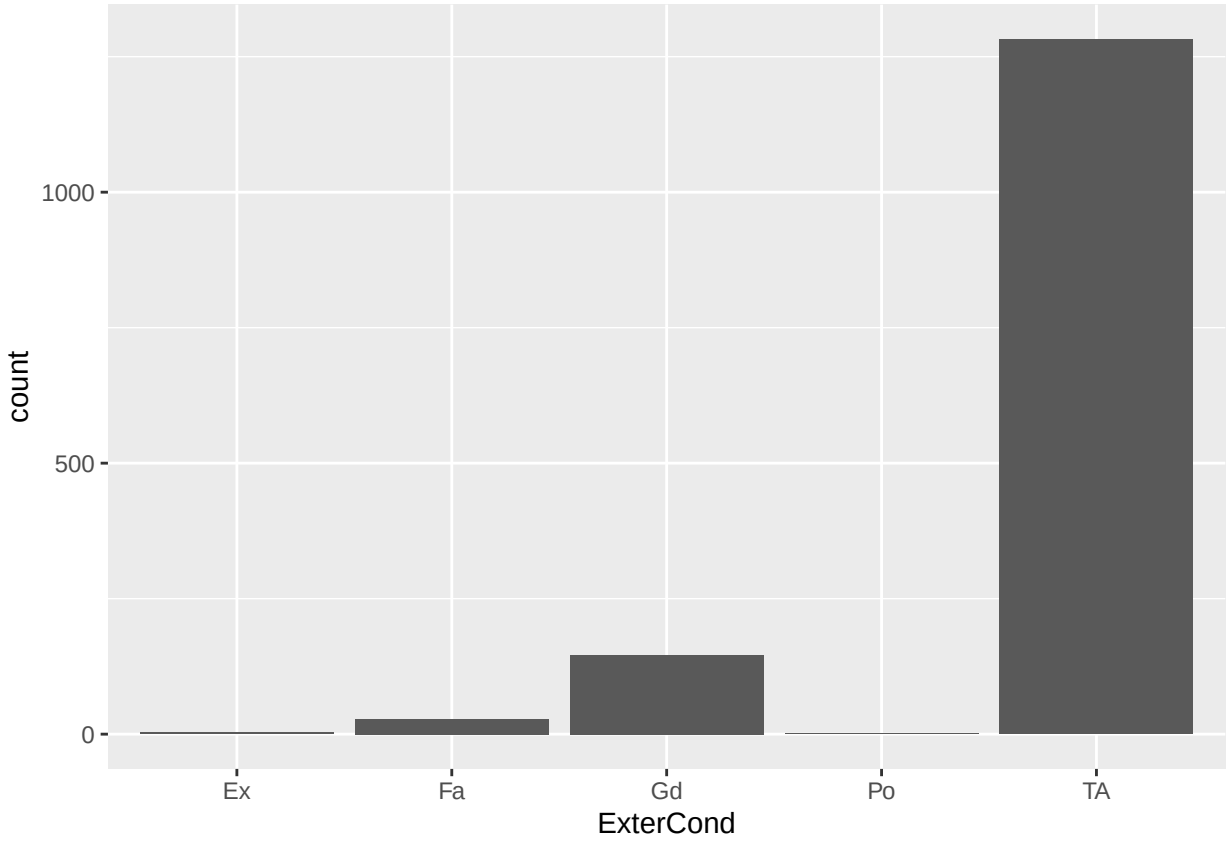
500
250
0
count
Ex
Fa
Gd
TA
ExterQual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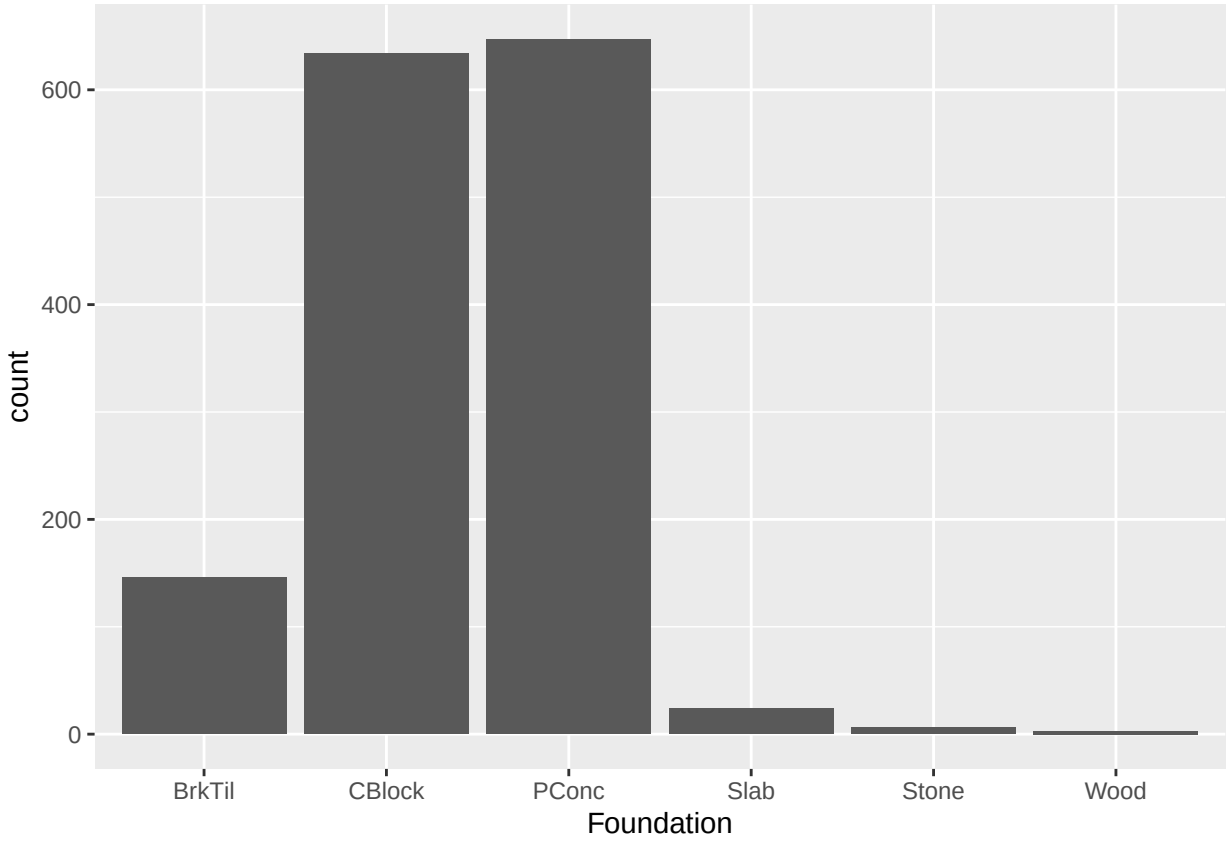
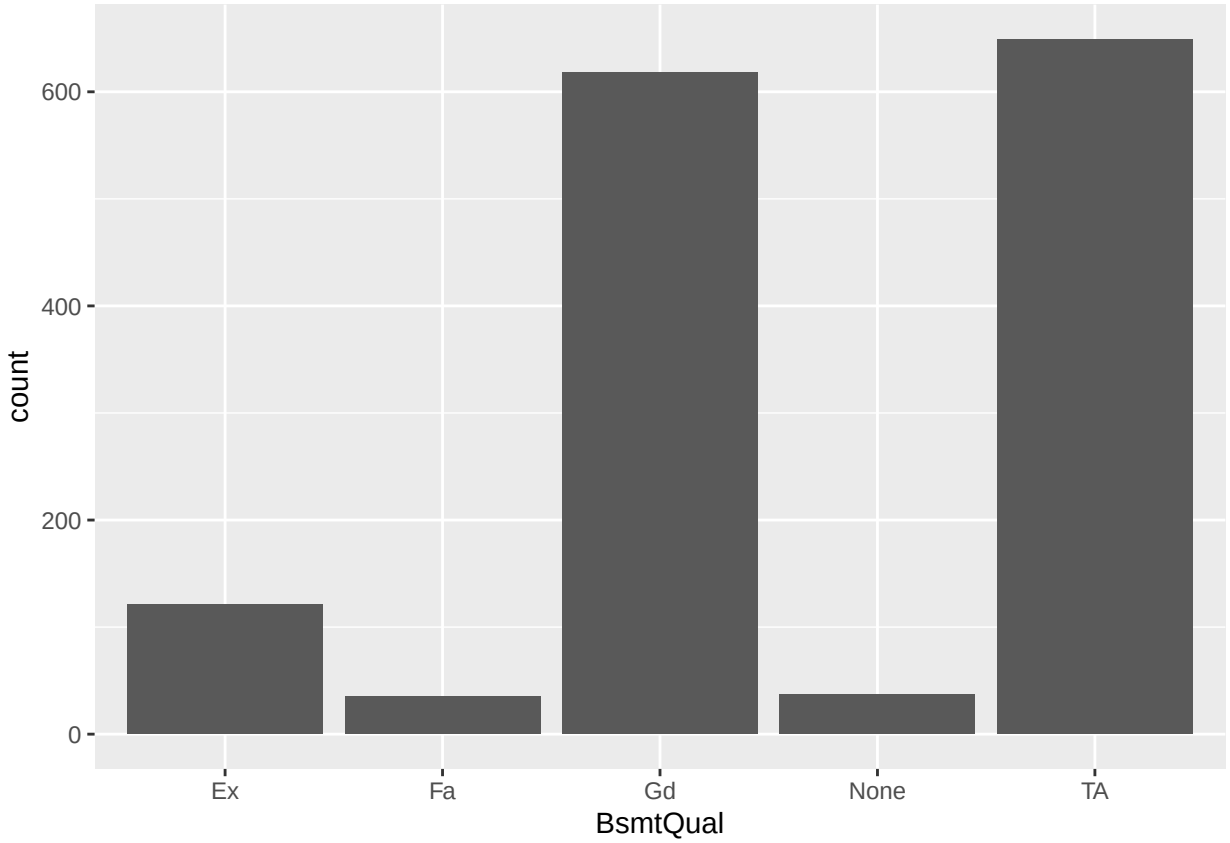
500
0
count
Ex
Fa
Gd
Po
TA
ExterCond


600
400
200
0
count
BrkTil
CBlock
PConc
Slab
Stone
Wood
Foundation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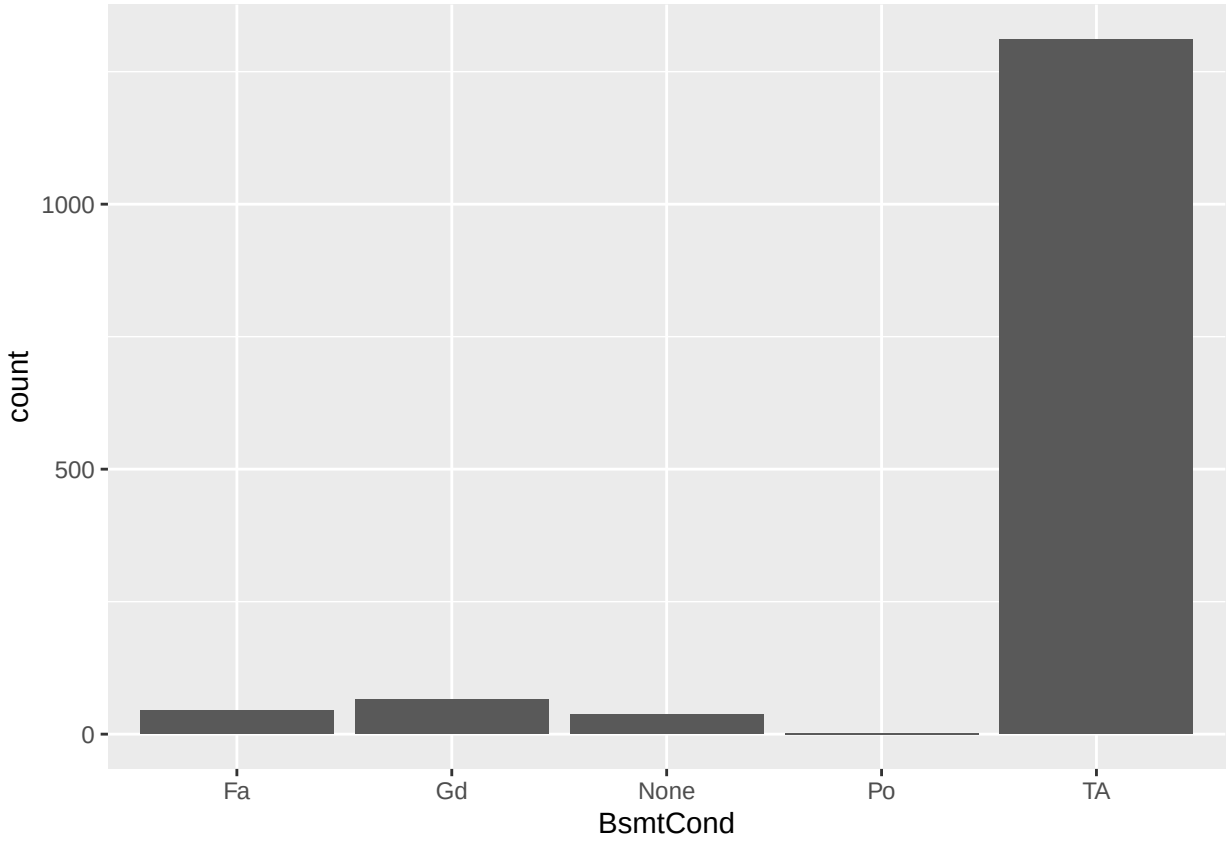
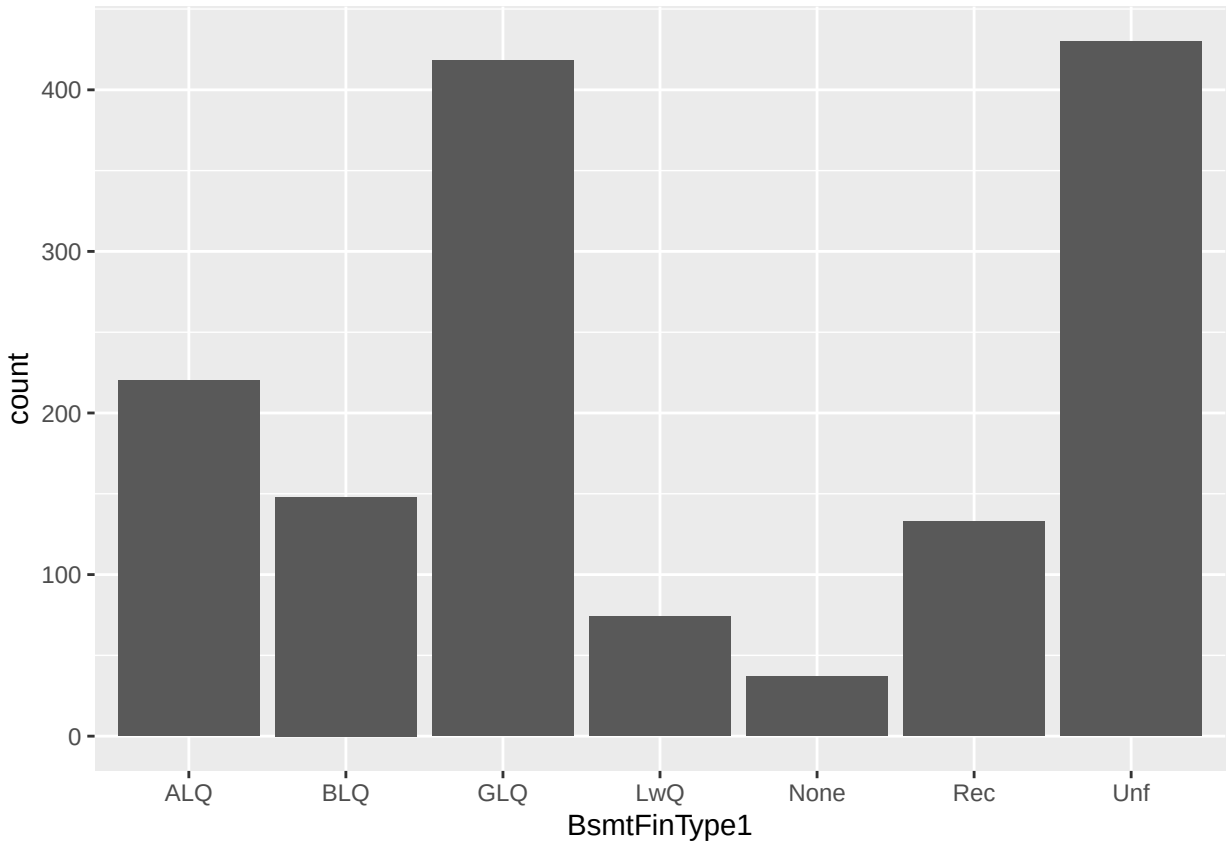
400
200
0
count
Ex
Fa
Gd
None
TA
BsmtQual


1000
500
0
count
Fa
Gd
None
Po
TA
BsmtCond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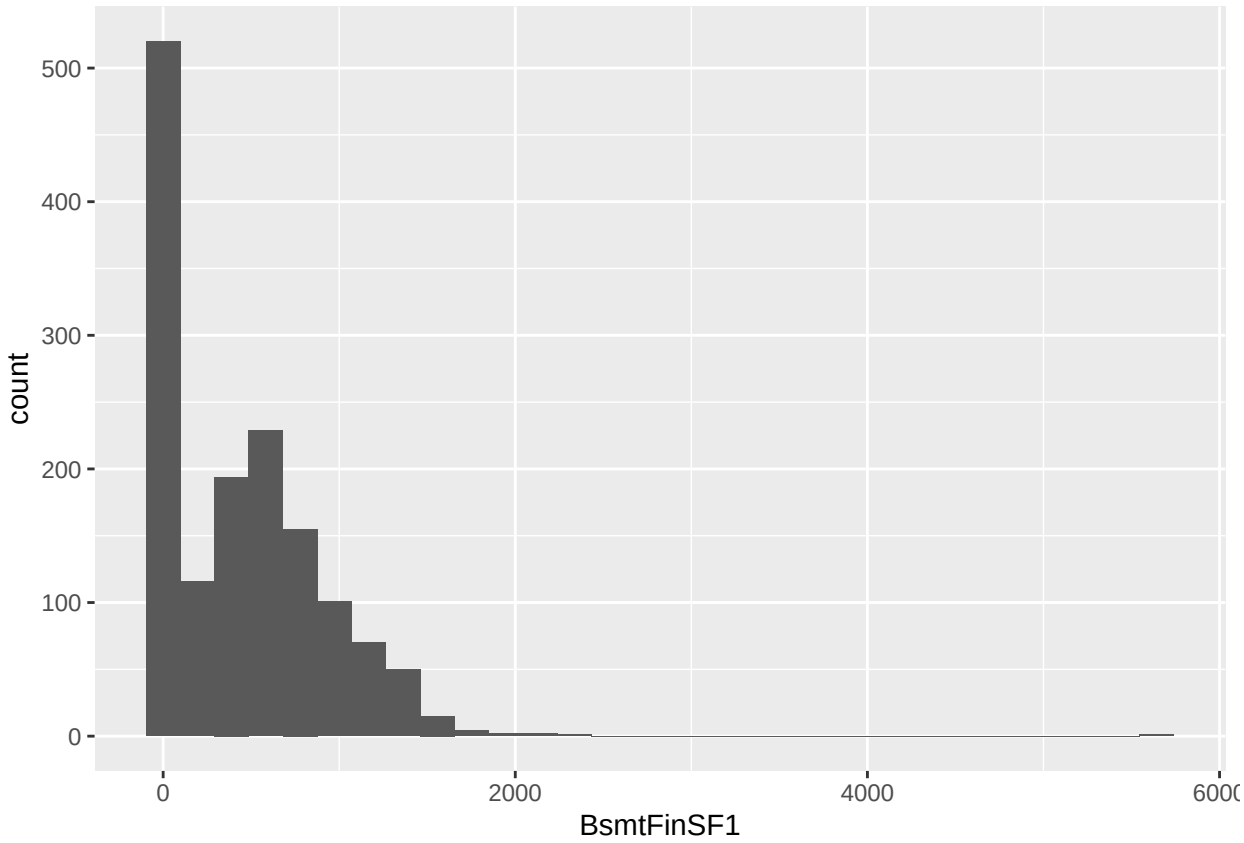
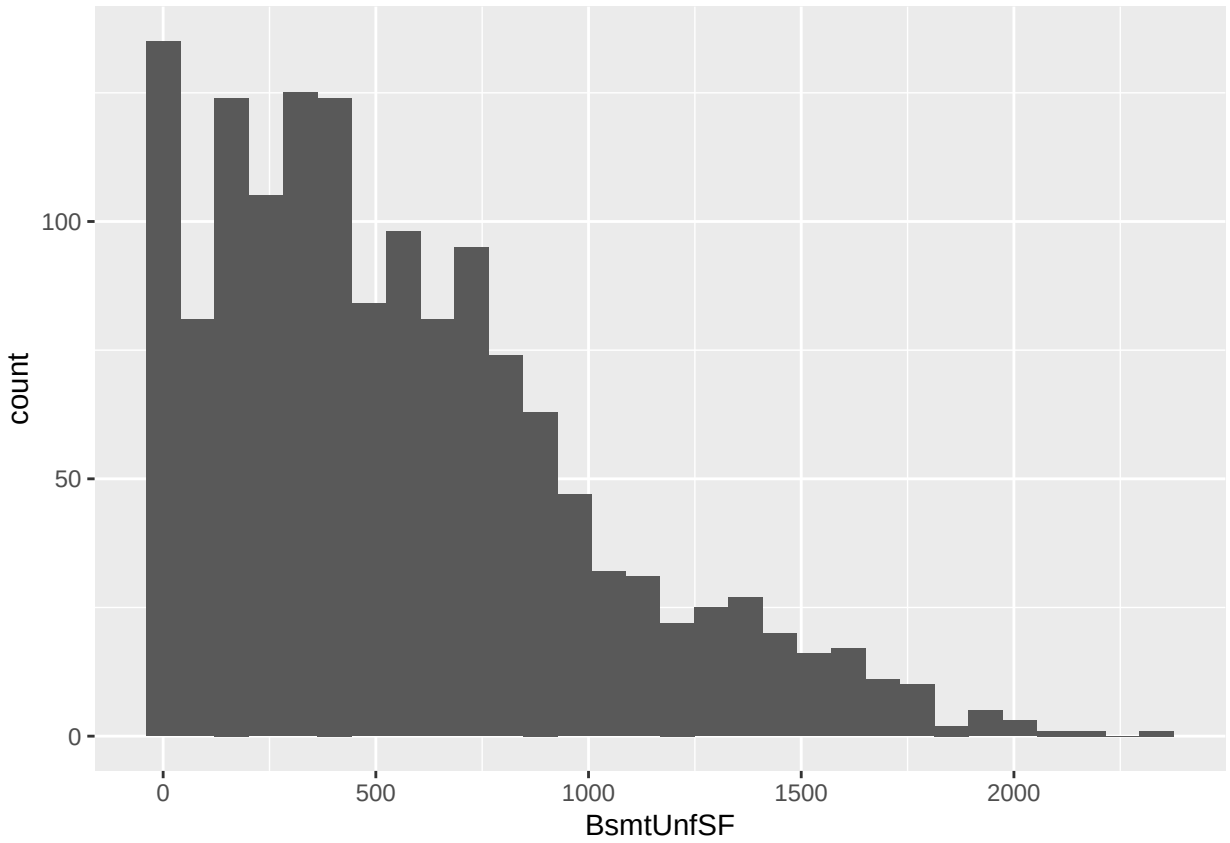
100
0
count
ALQ
BLQ
GLQ
LwQ
None
Rec
Unf
BsmtFinType1


500
400
300
200
100
0
count
0
2000
4000
6000
BsmtFinSF1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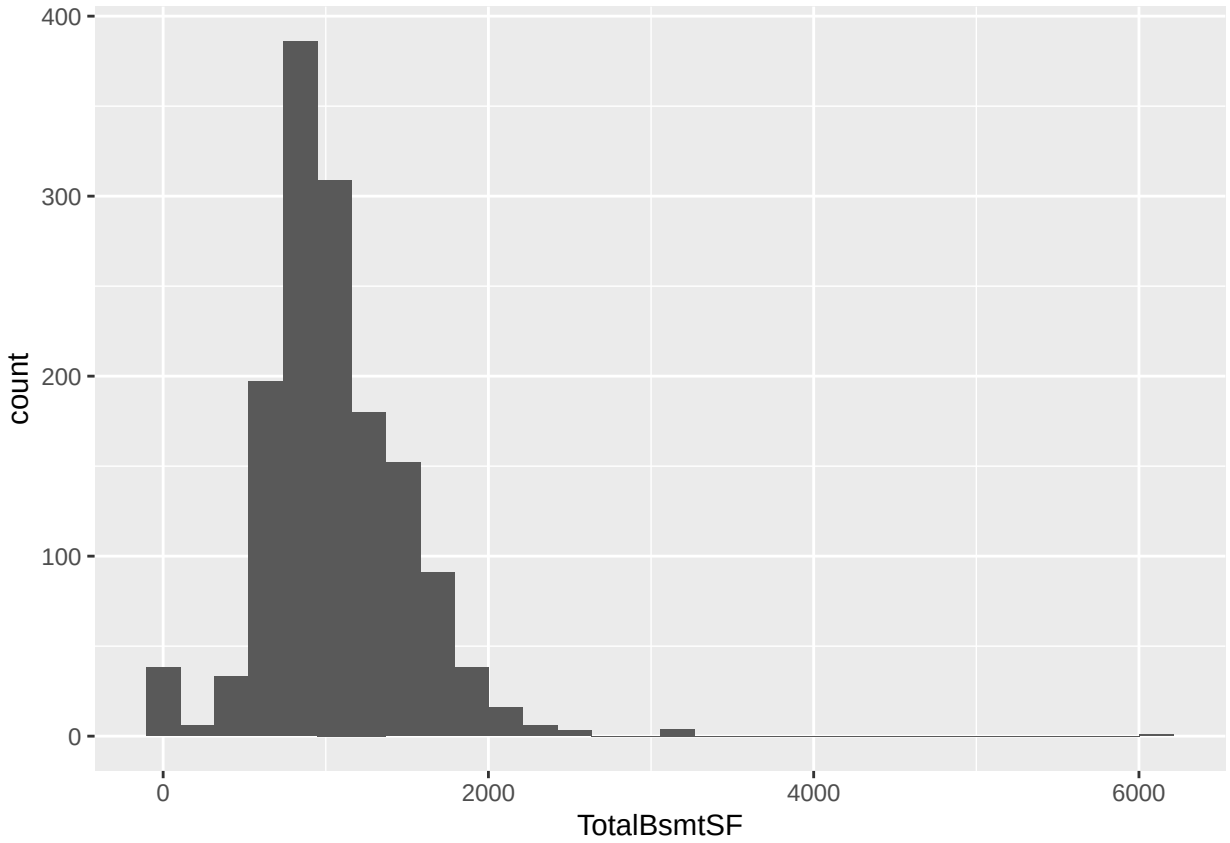
2000
BsmtUnfSF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4000
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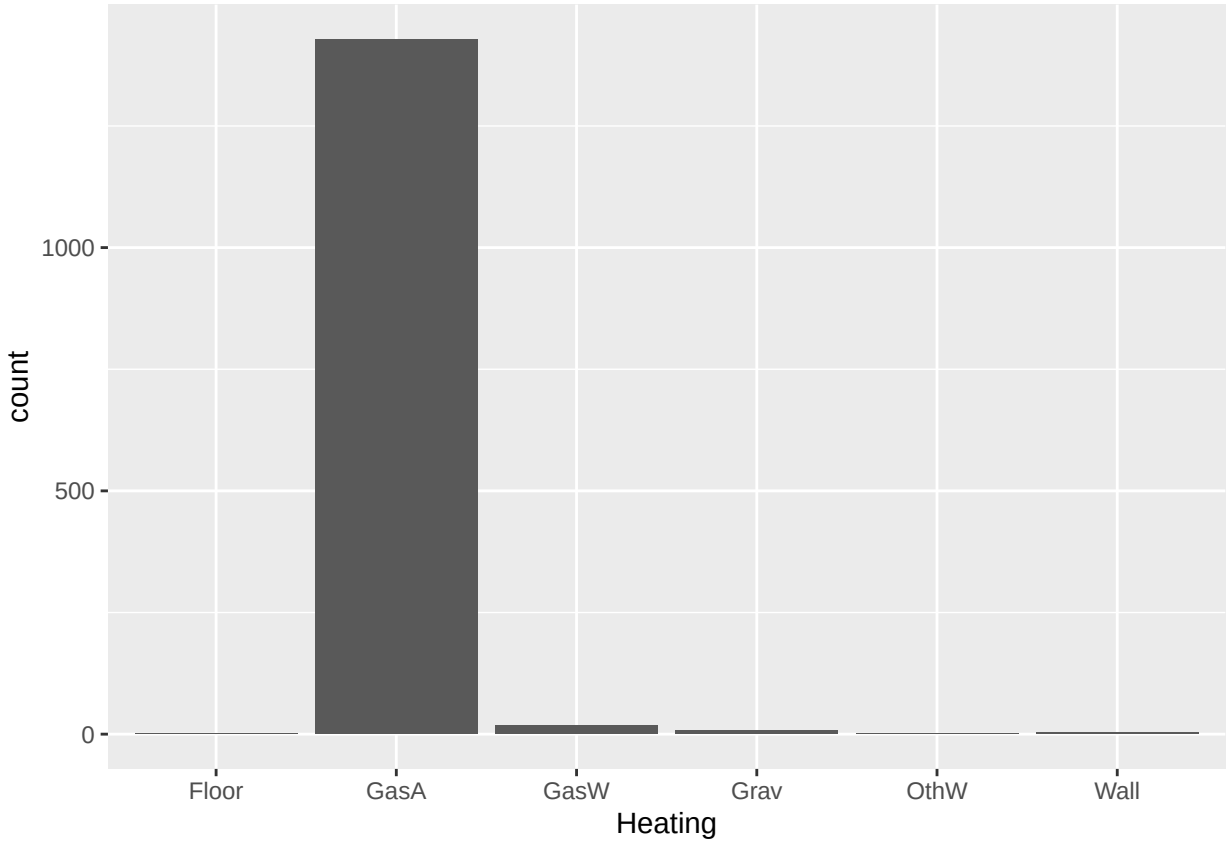
TotalBsmtSF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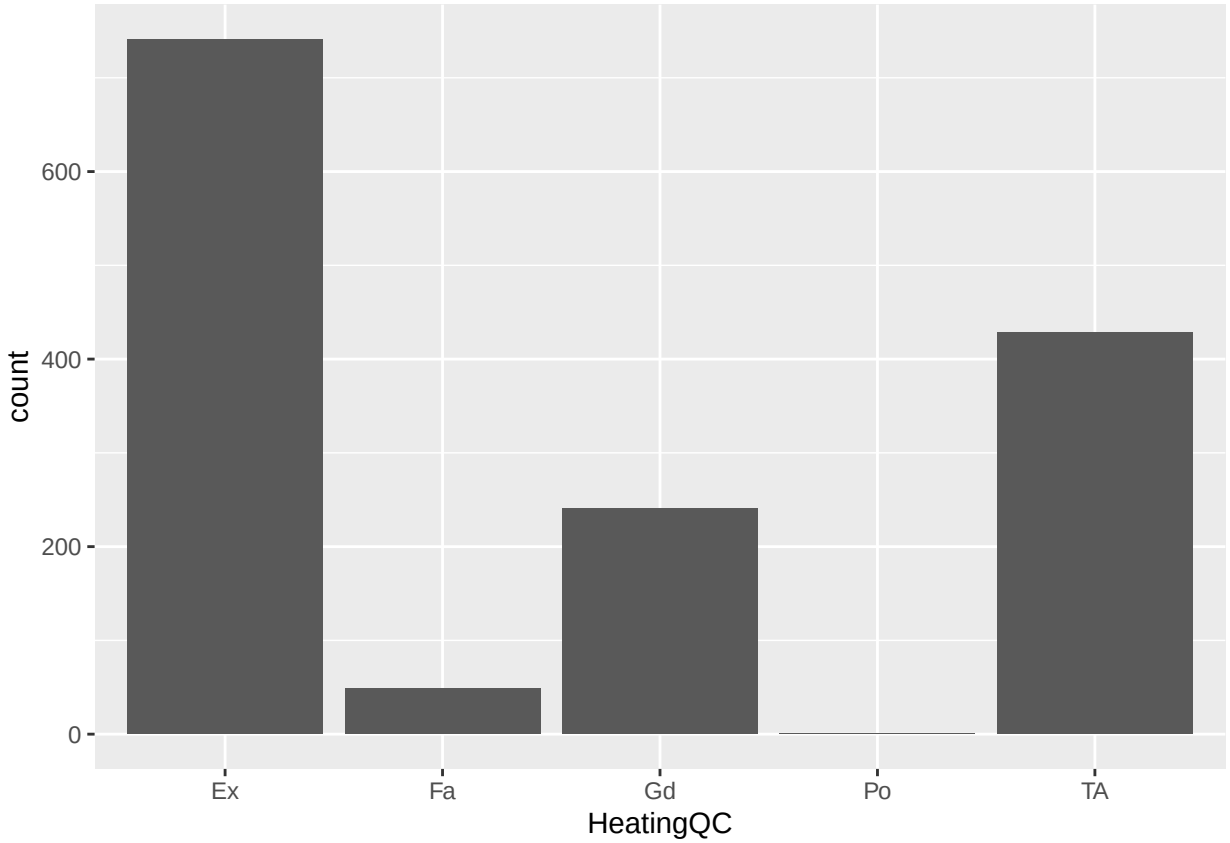
GasA
GasW
Grav
OthW
Wall
Heating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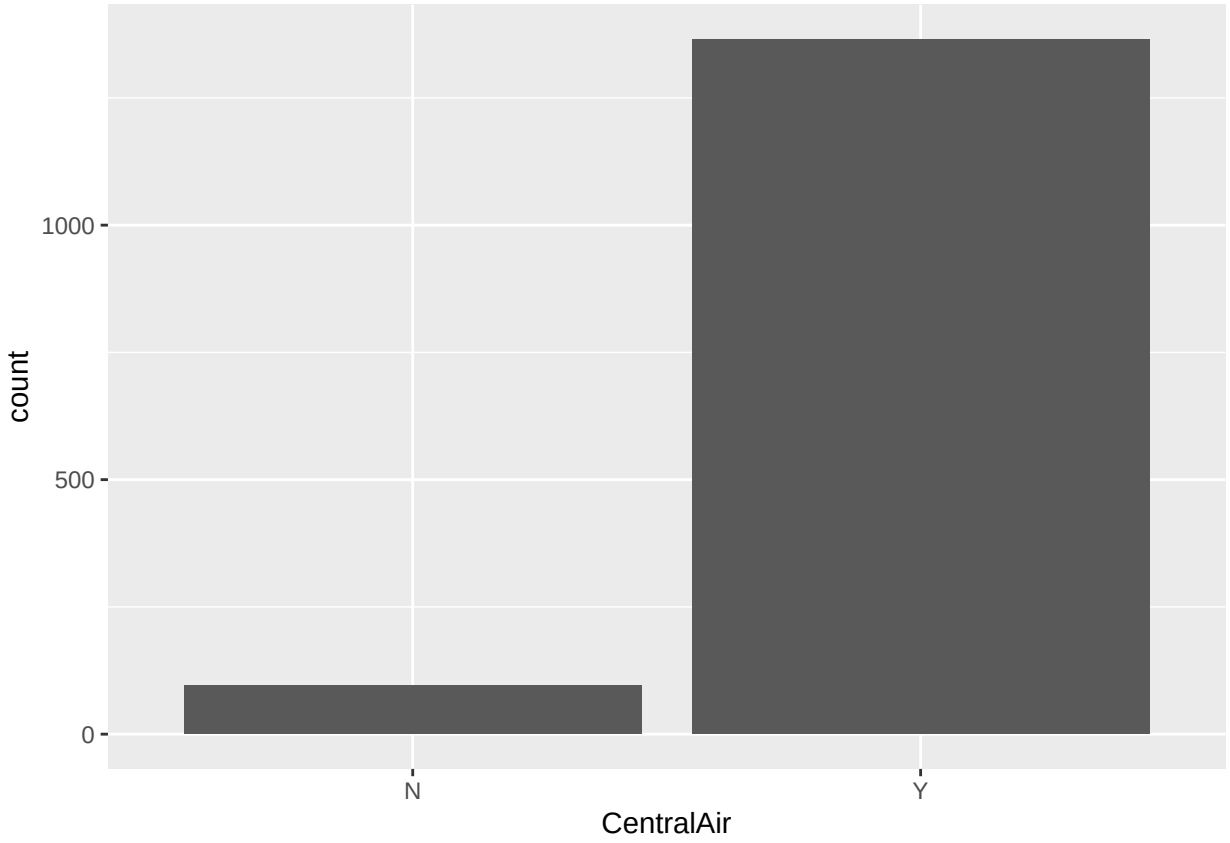
Ex
Fa
Gd
Po
TA
HeatingQC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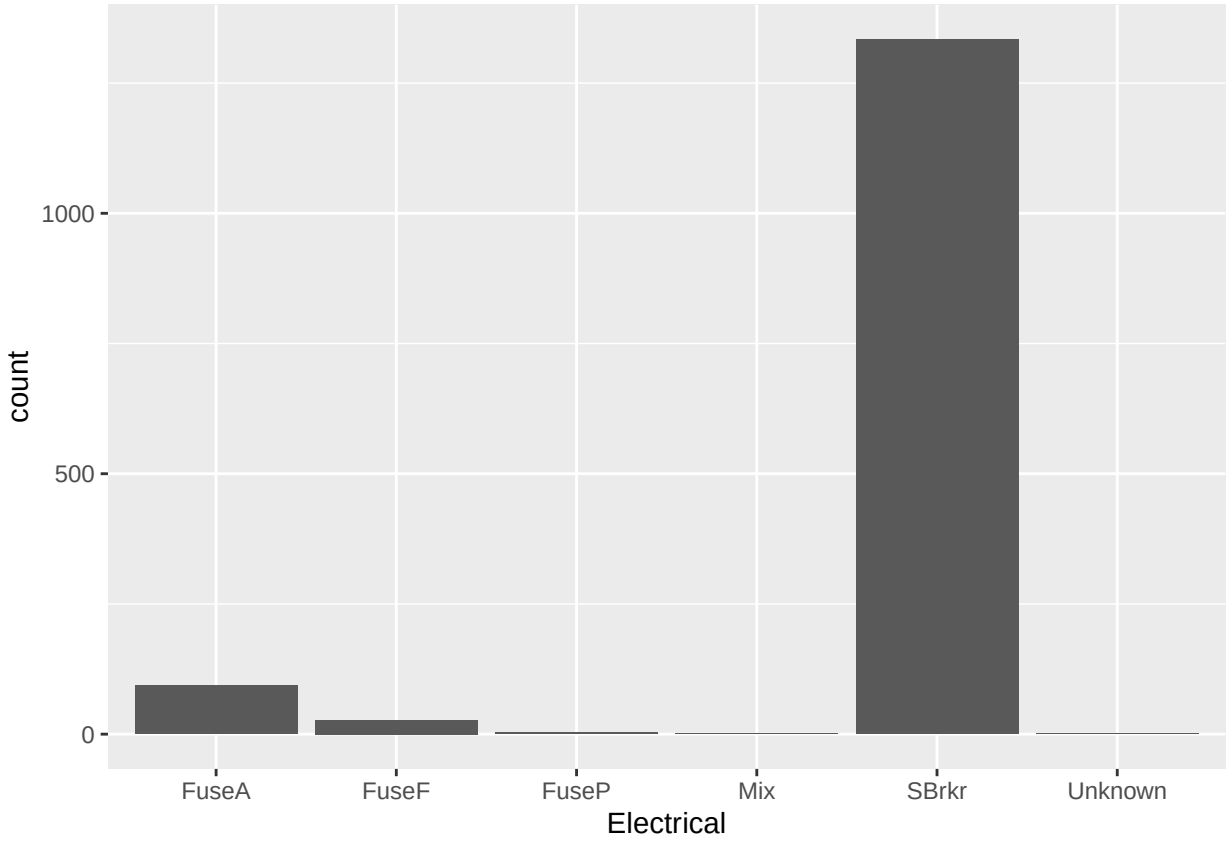
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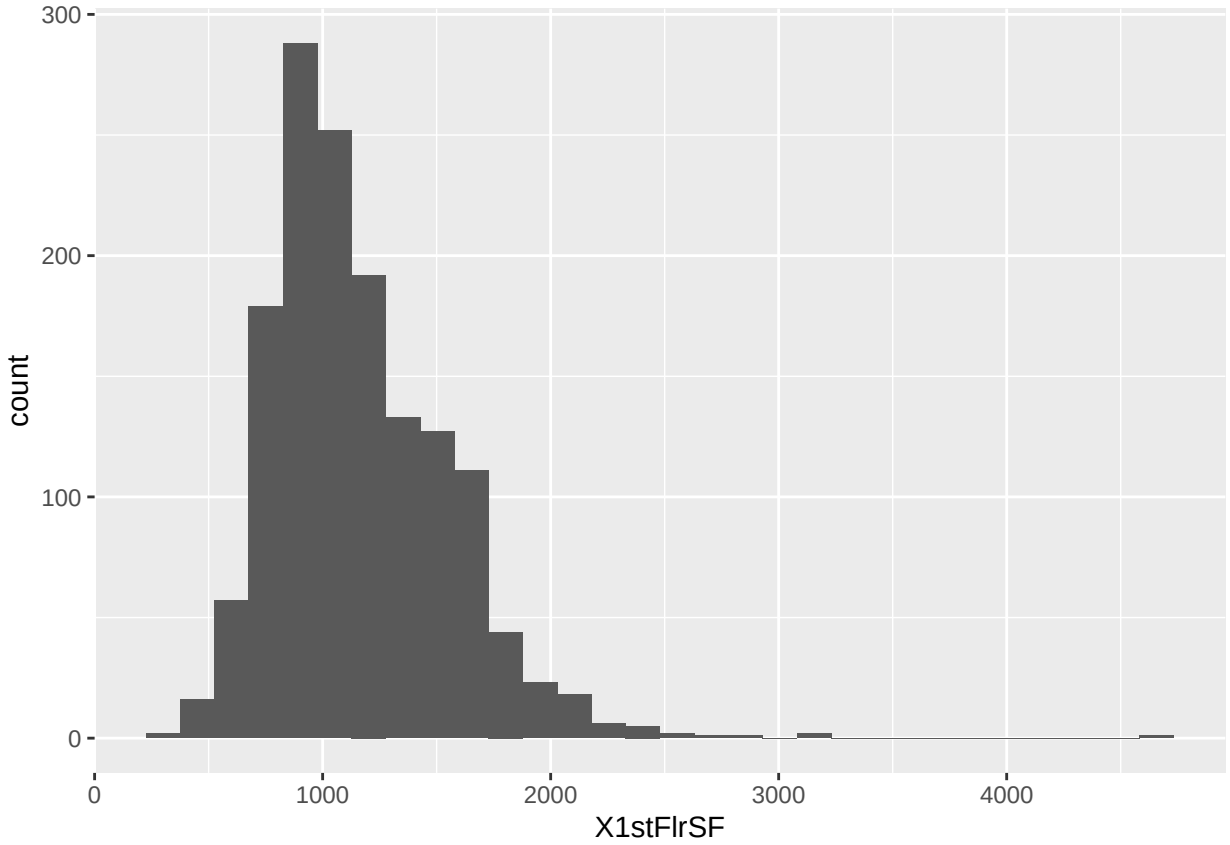
FuseF
FuseP
Mix
SBrkr
Unknown
Electrical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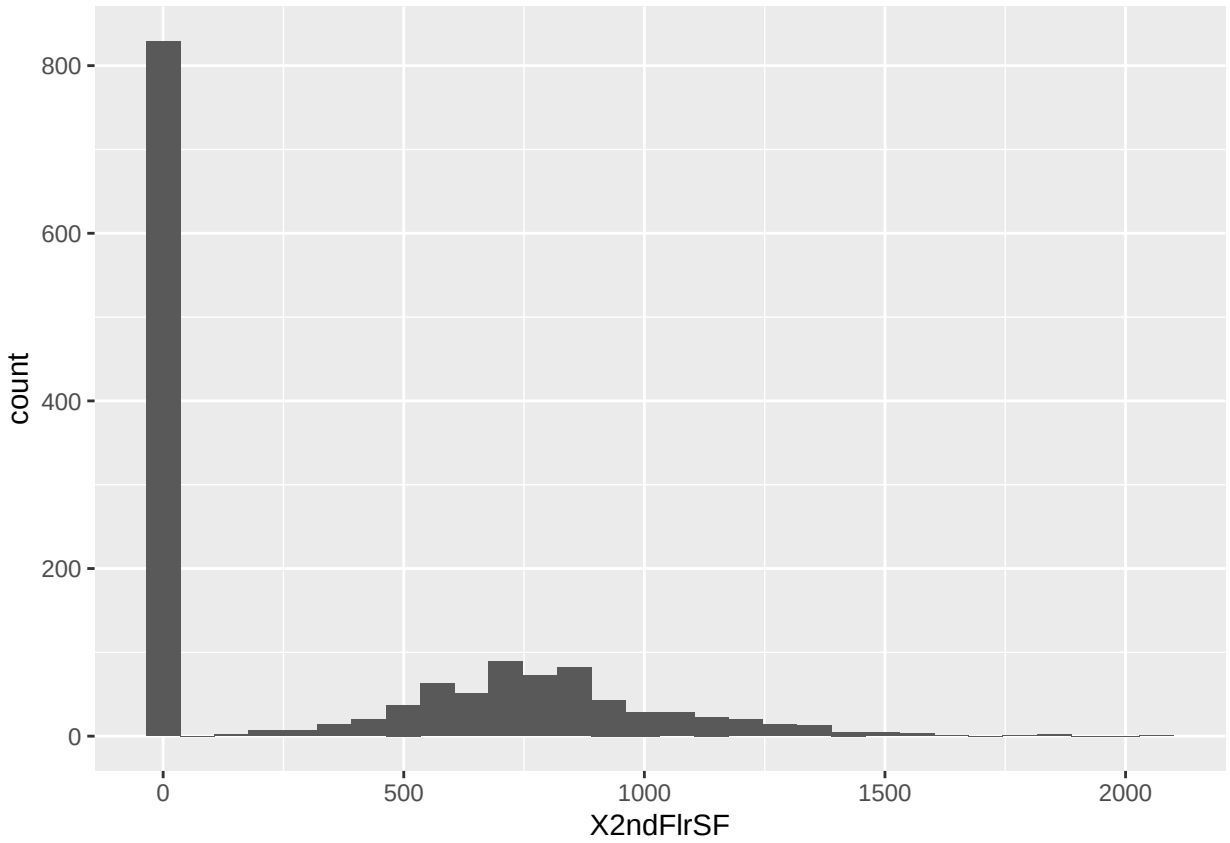
4000
X1stFlrSF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1500
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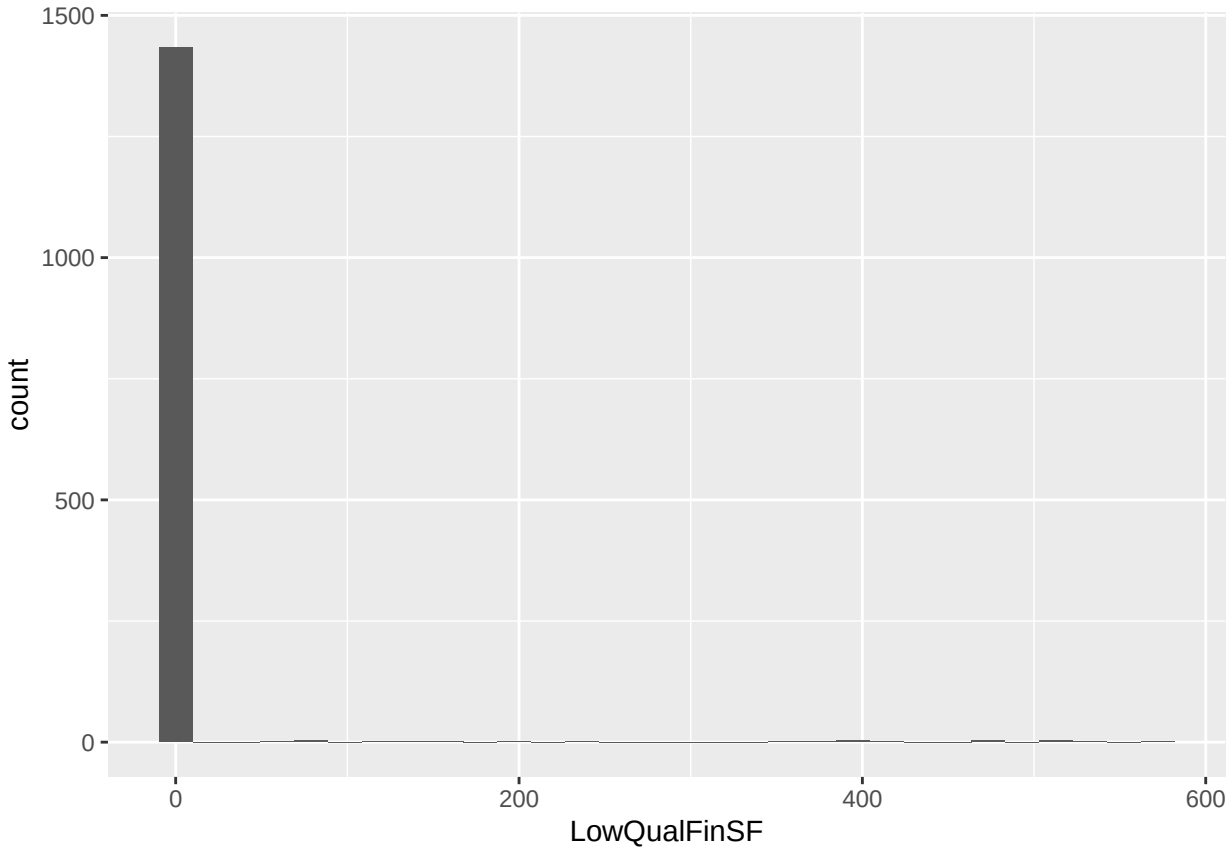
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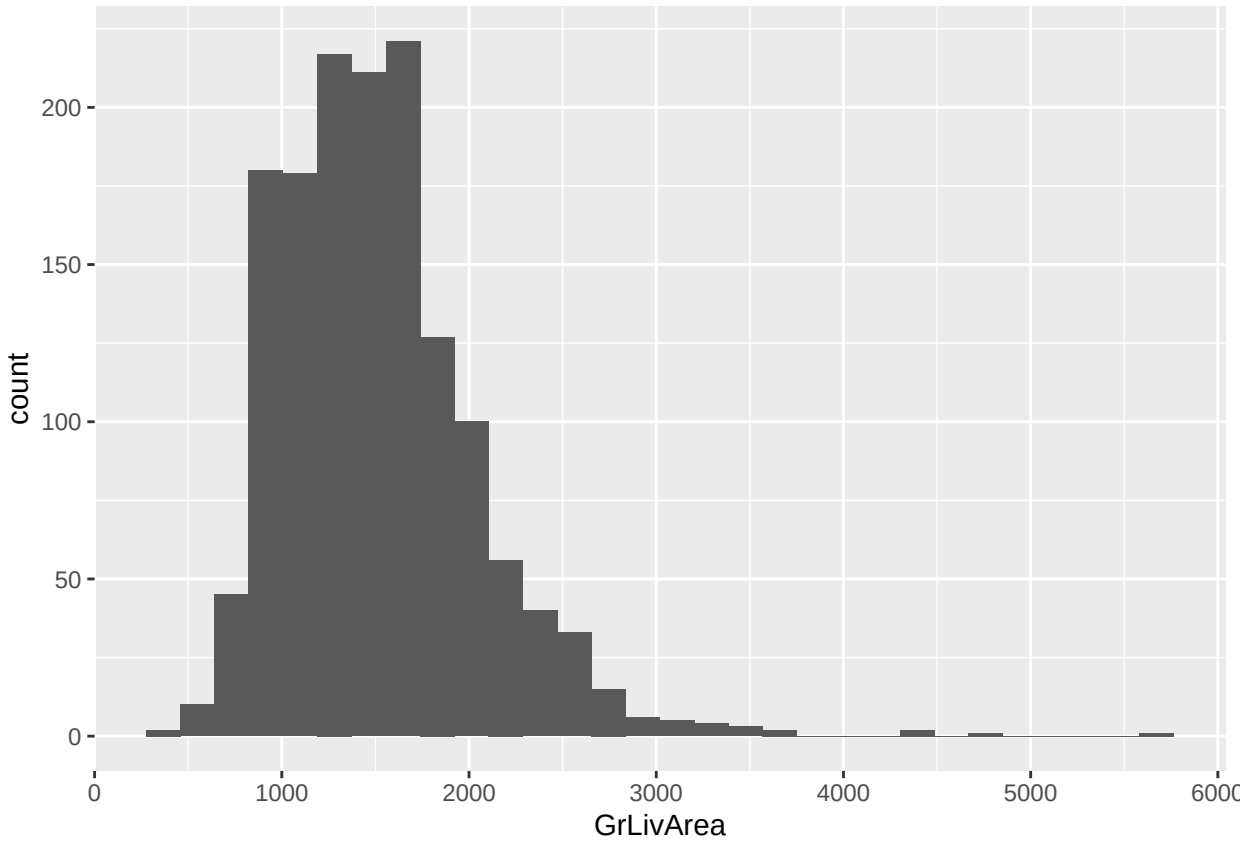
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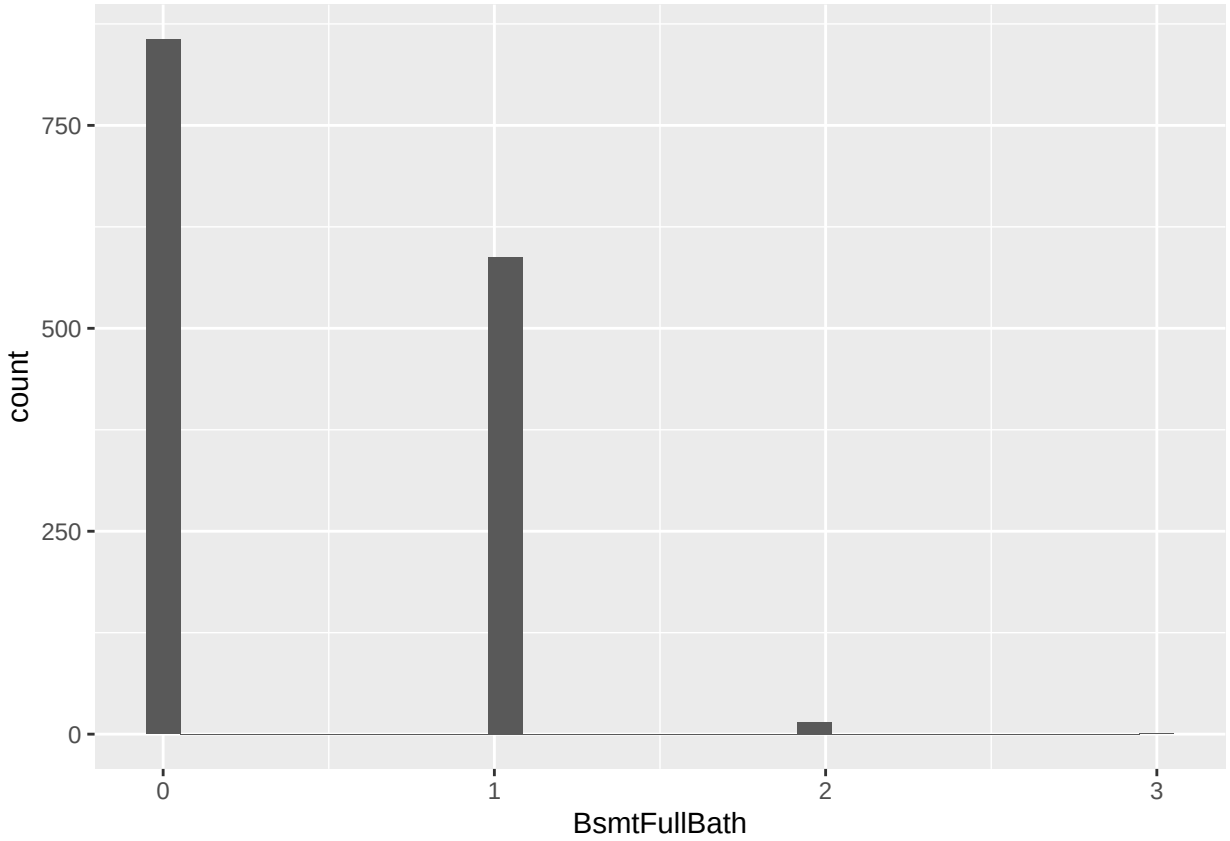
4000
5000
6000
GrLivArea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count
0
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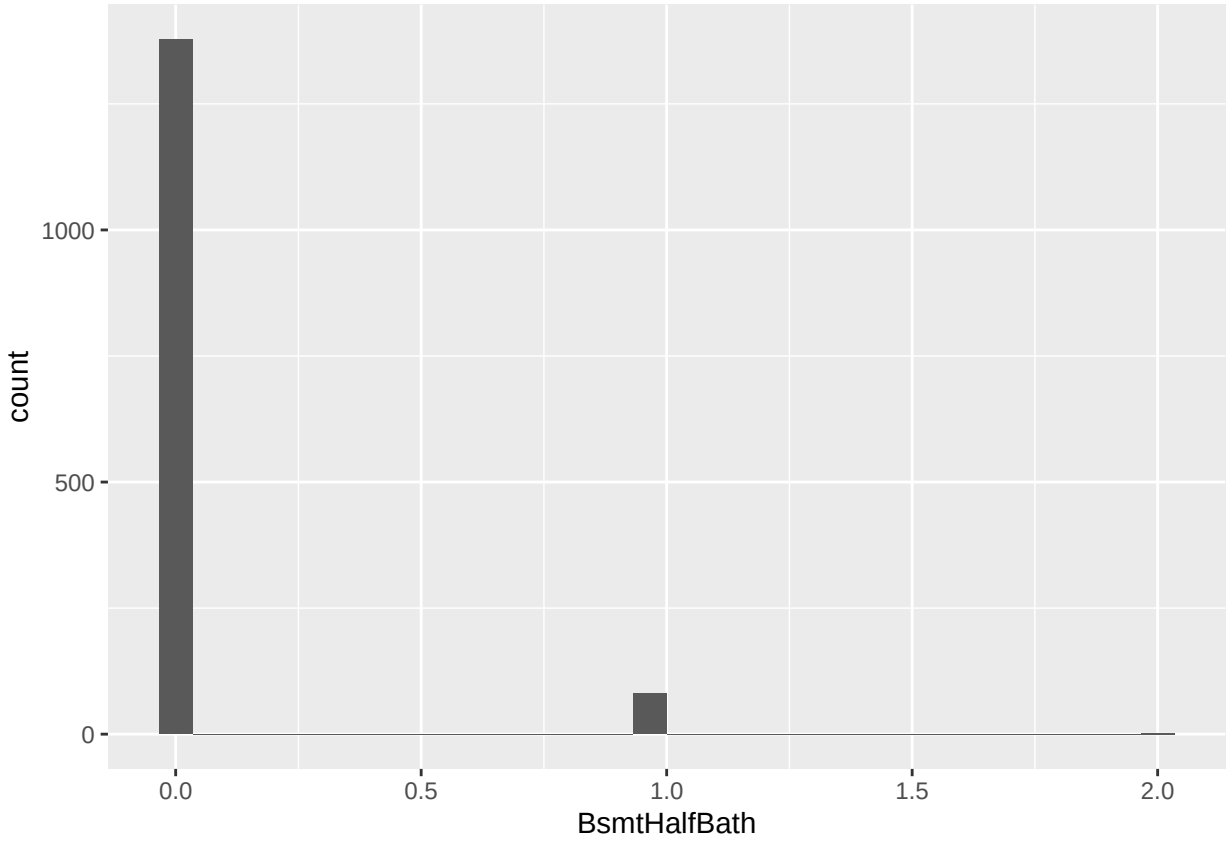
2
3
BsmtFullBath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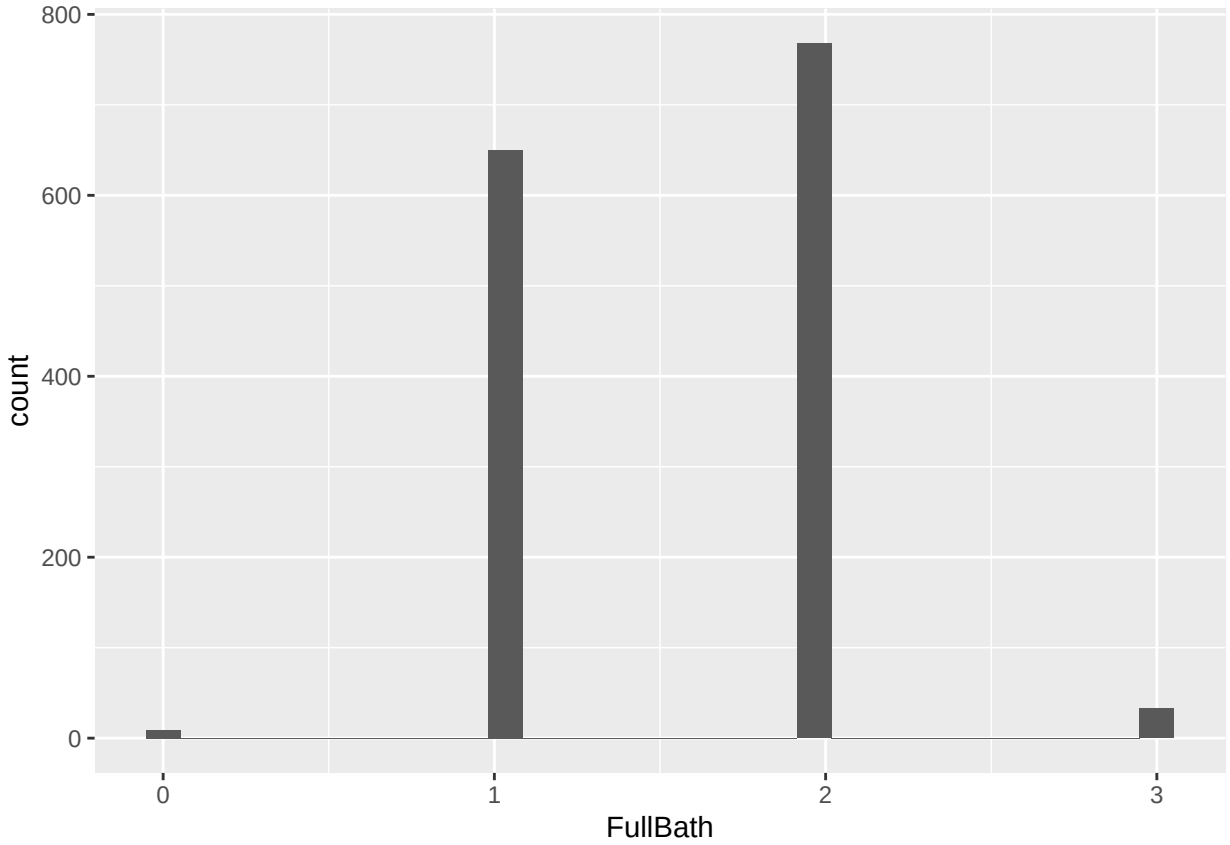
0.0
0.5
1.0
1.5
2.0
BsmtHalfBath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600
400
200
0
count
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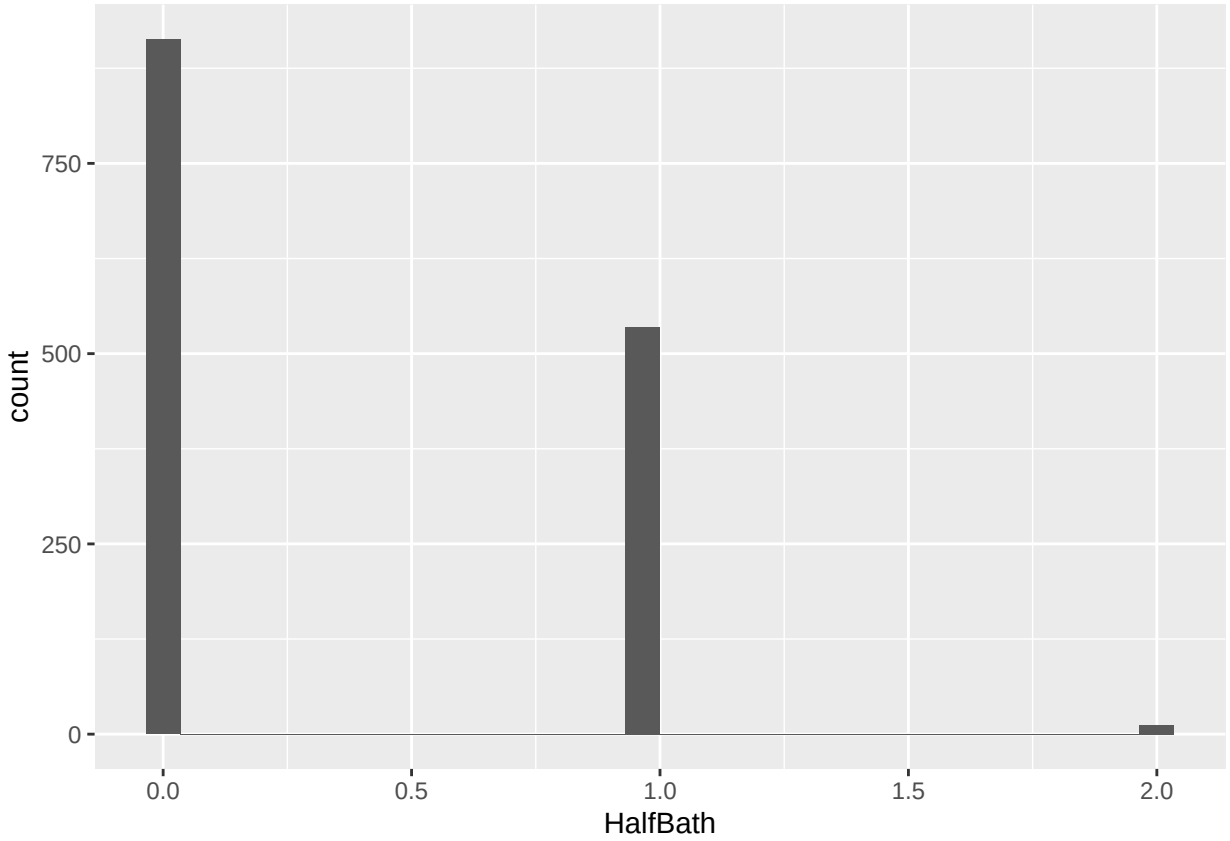
1
2
3
FullBath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count
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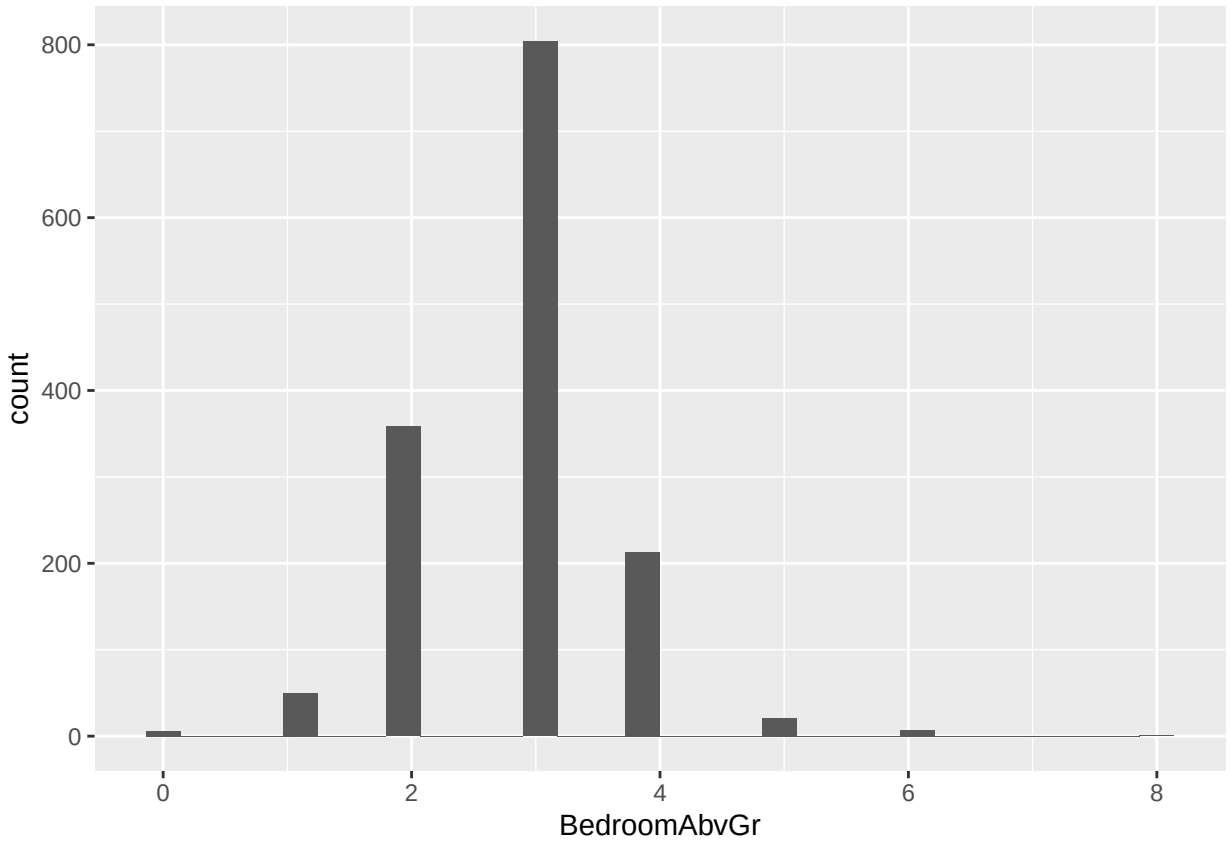
1.5
2.0
HalfBath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600
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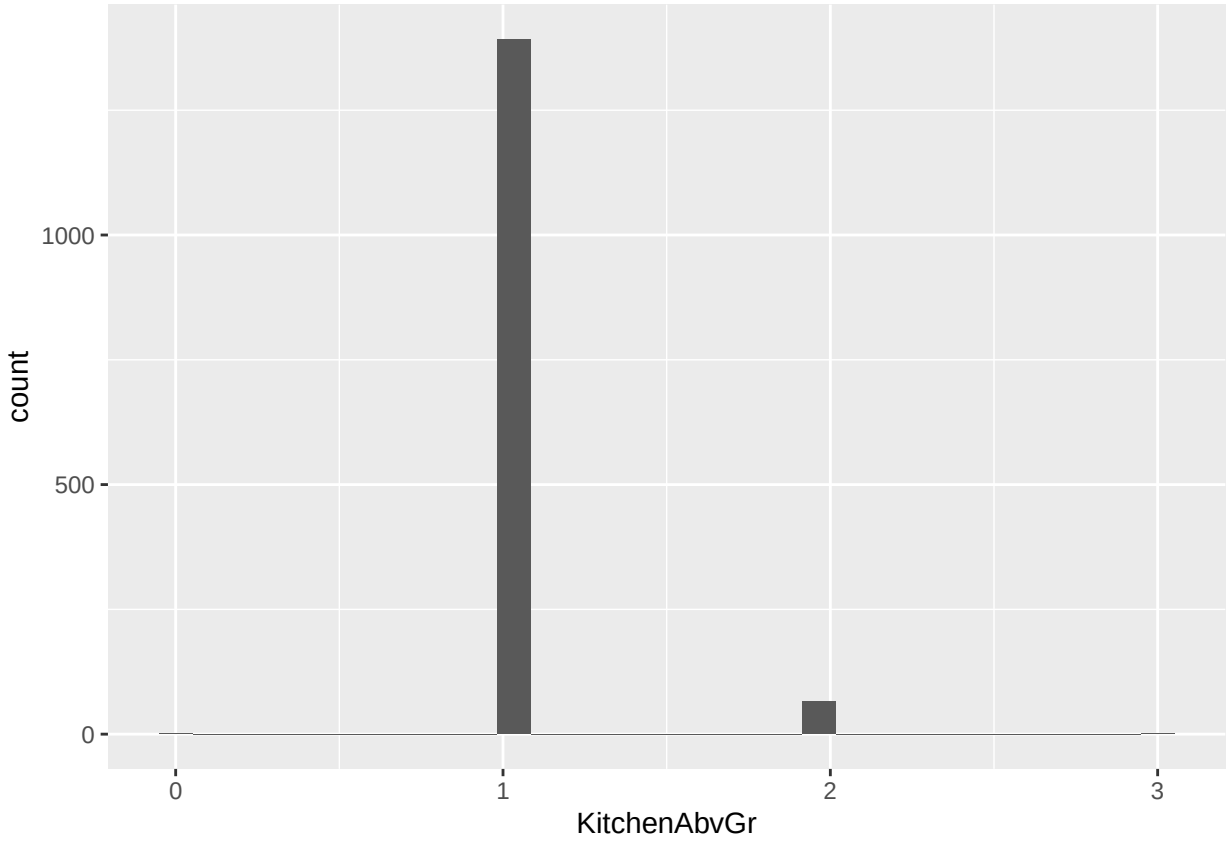
0
count
0
2
4
6
8
BedroomAbvGr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count
0
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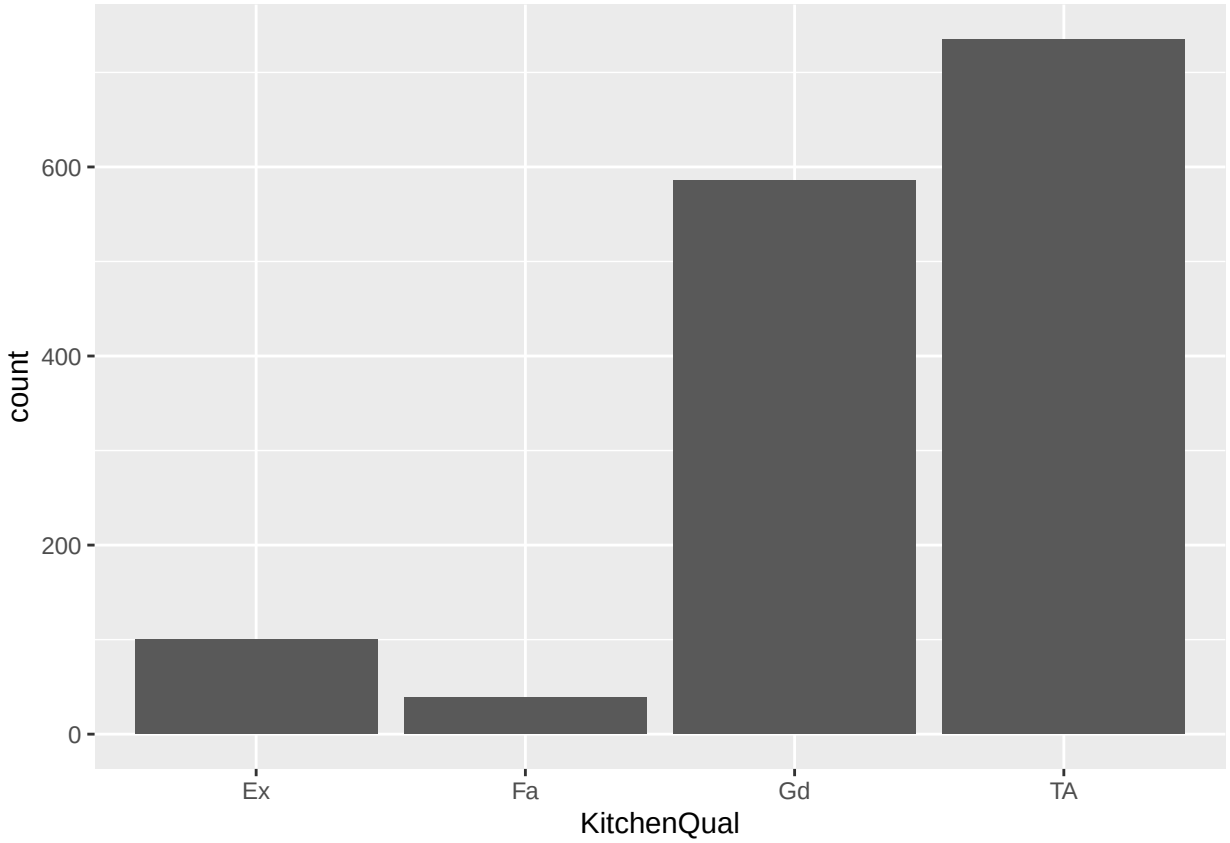
2
3
KitchenAbvGr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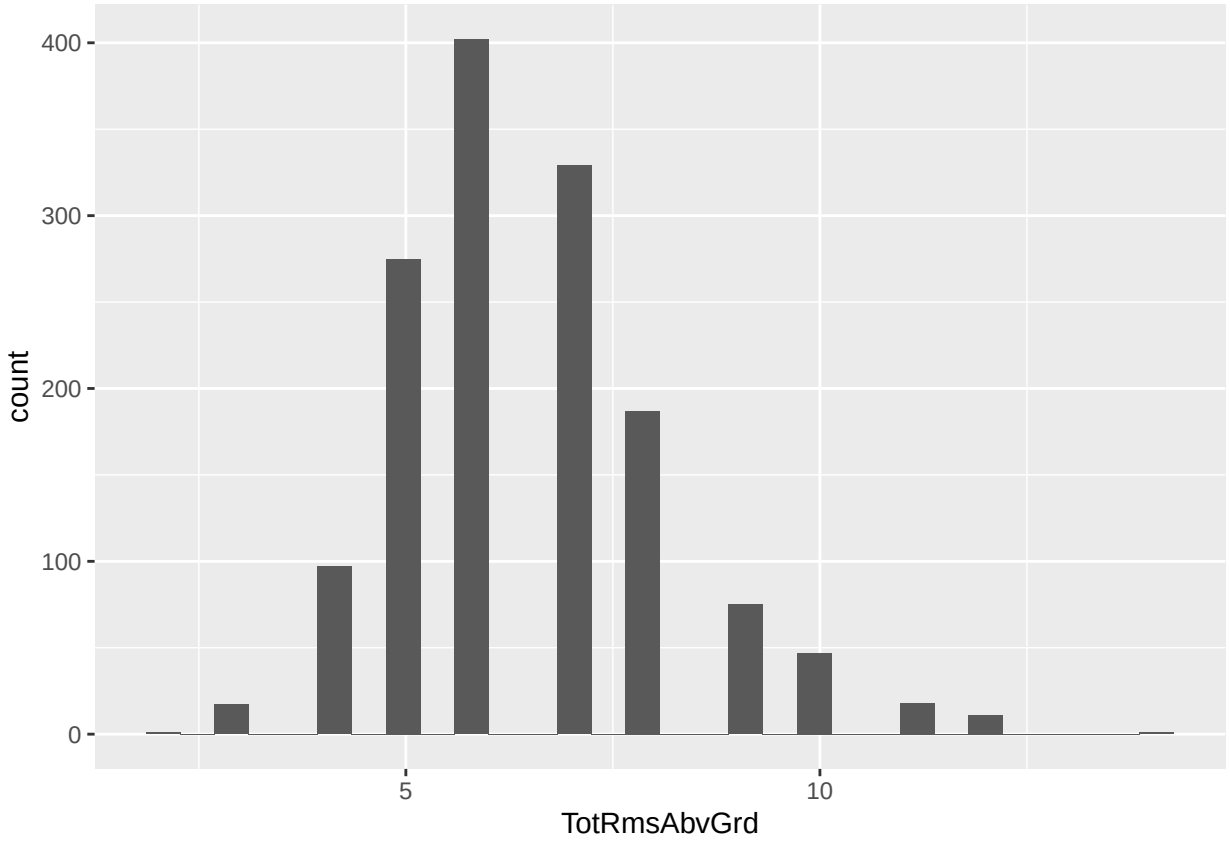
count
Ex
Fa
Gd
TA
KitchenQual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10
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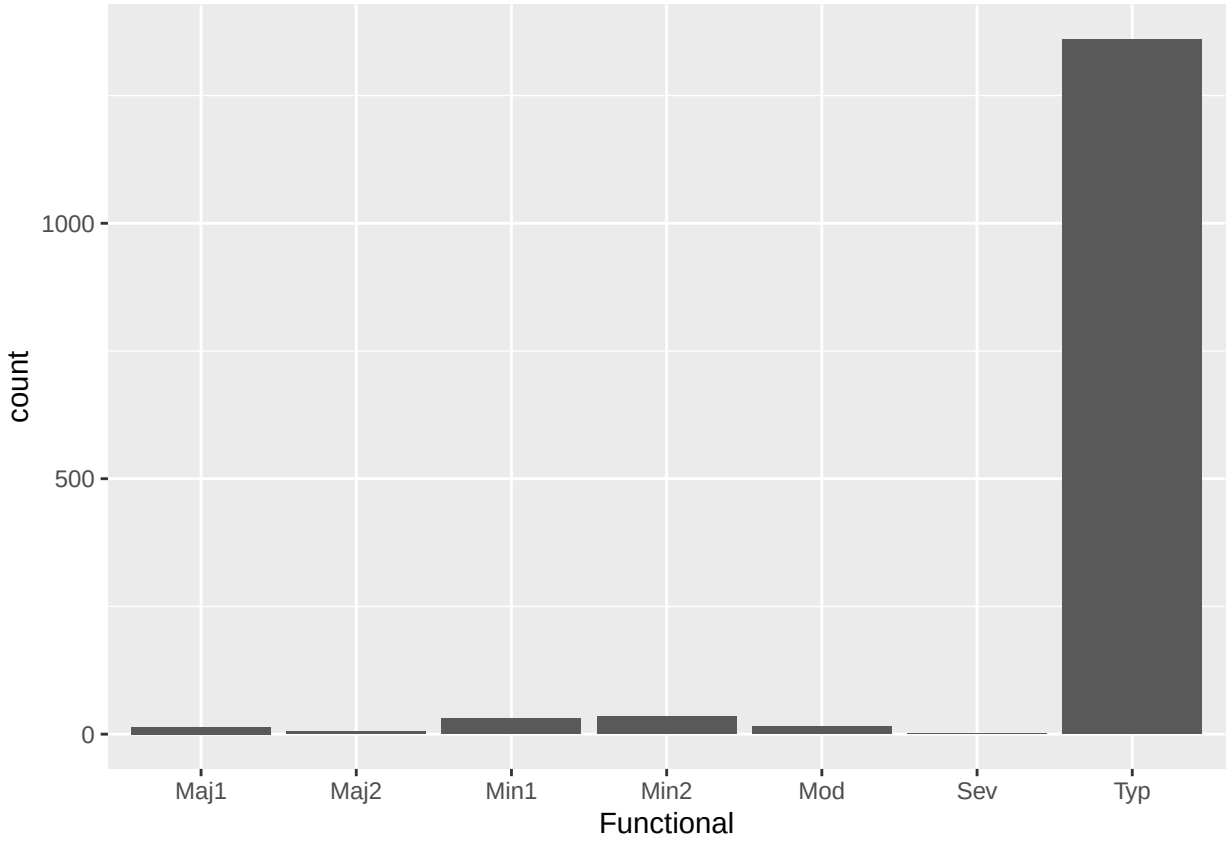
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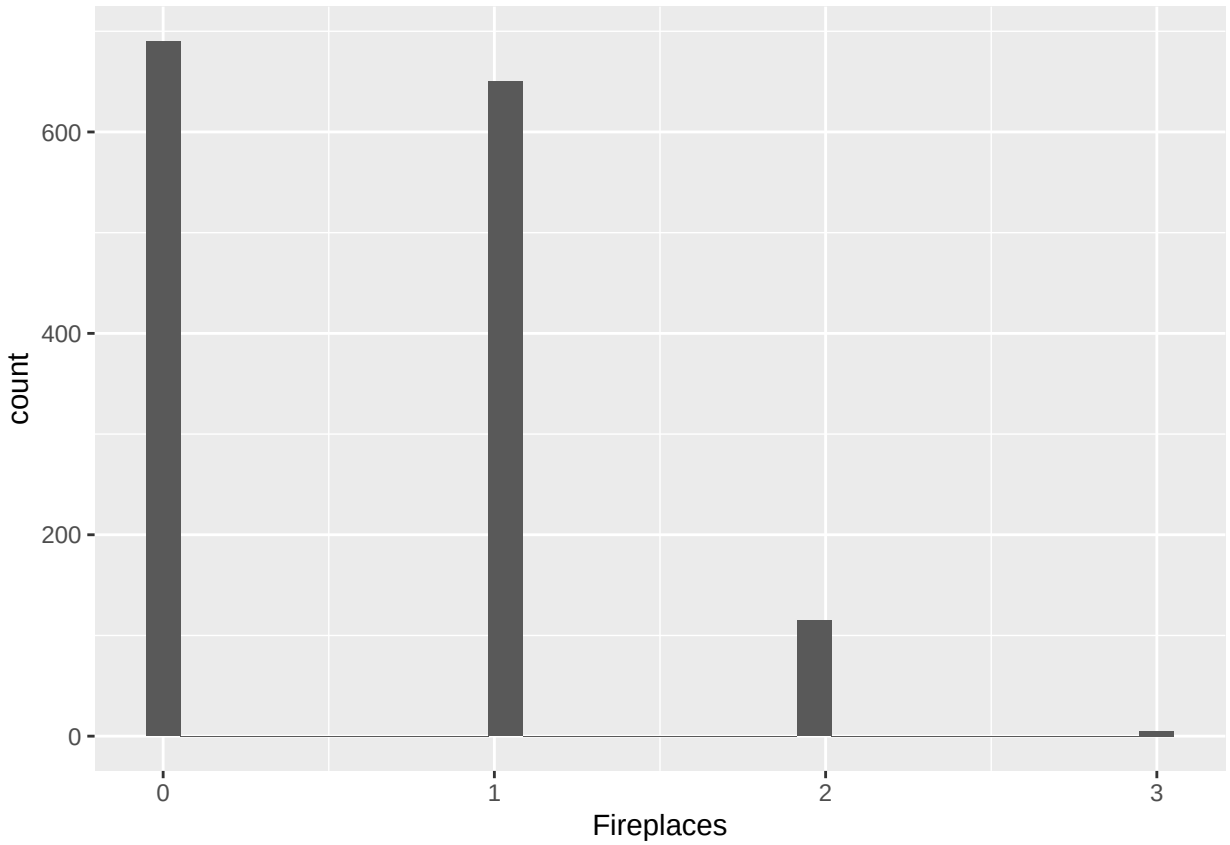
Maj1
Maj2
Min1
Min2
Mod
Sev
Typ
Functional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3
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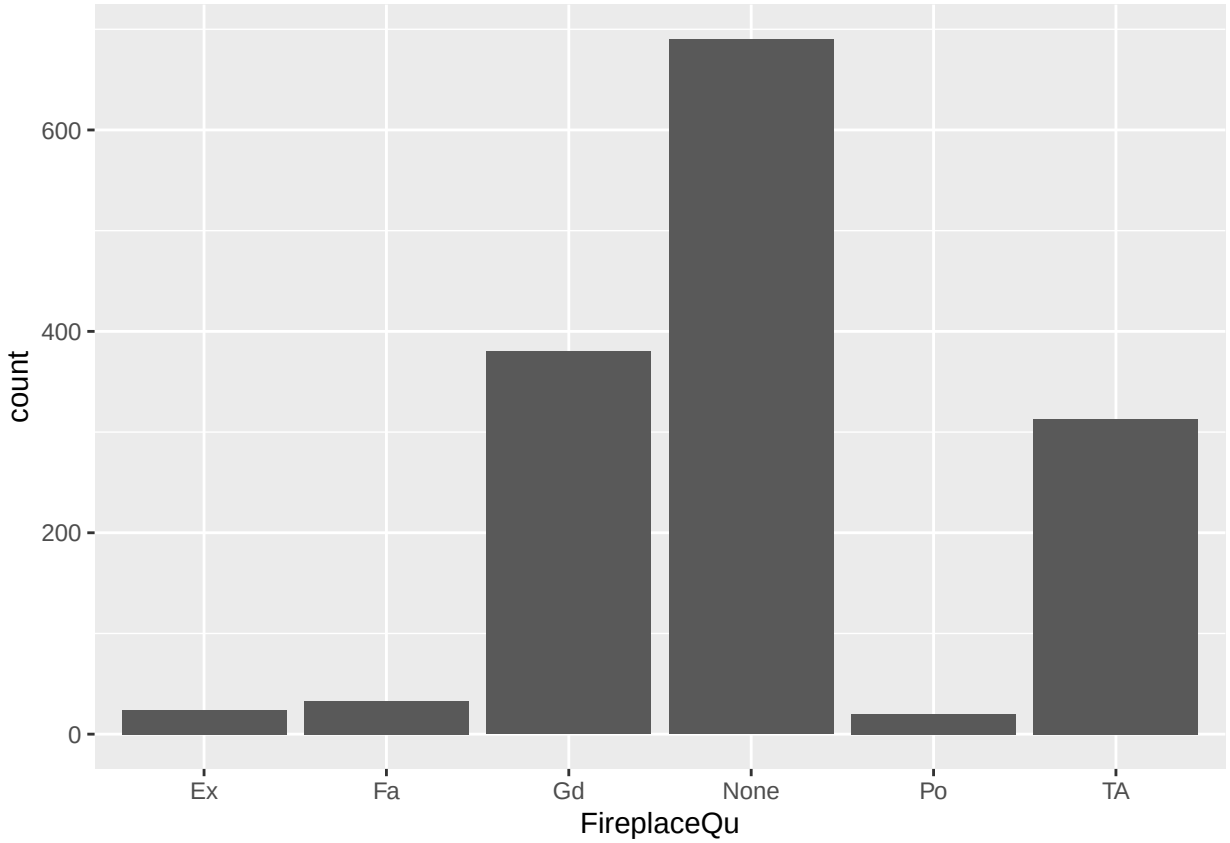
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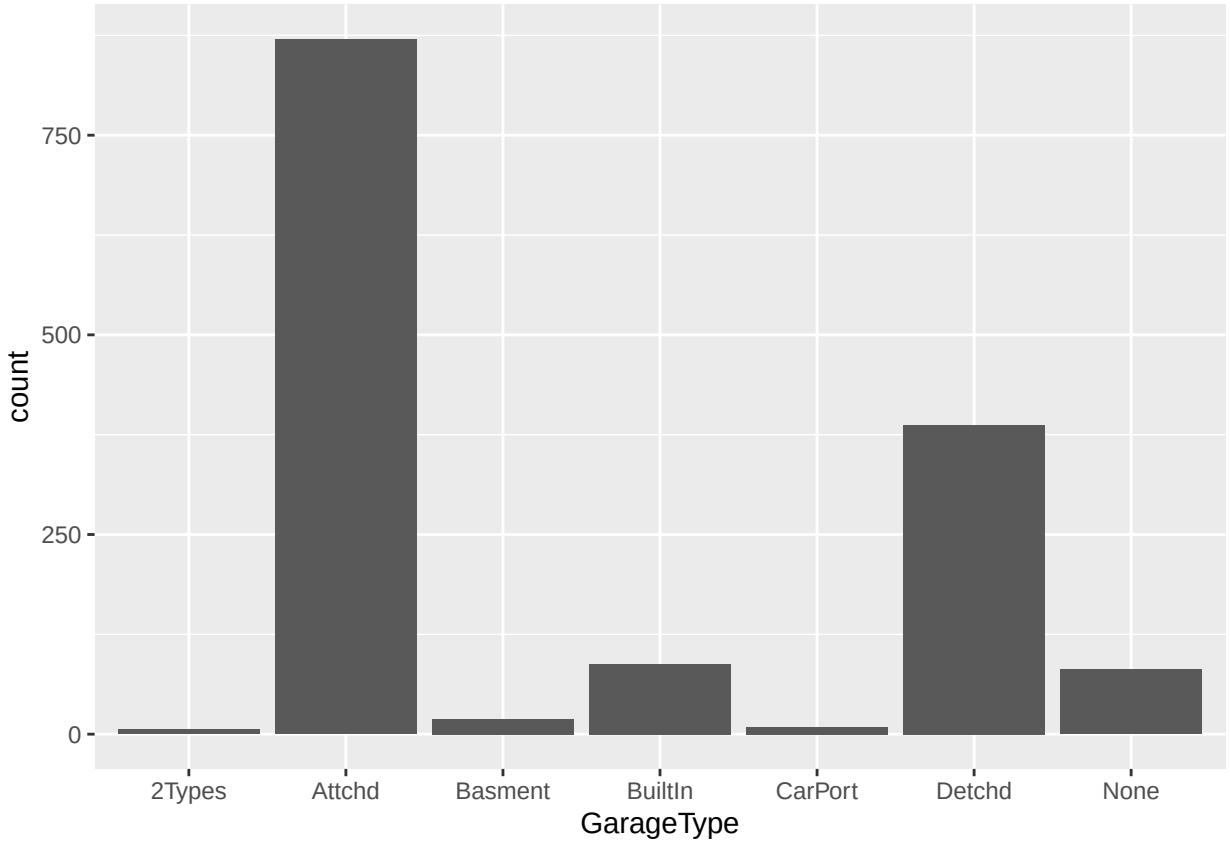
FireplaceQu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count
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Basment
BuiltIn
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Detchd
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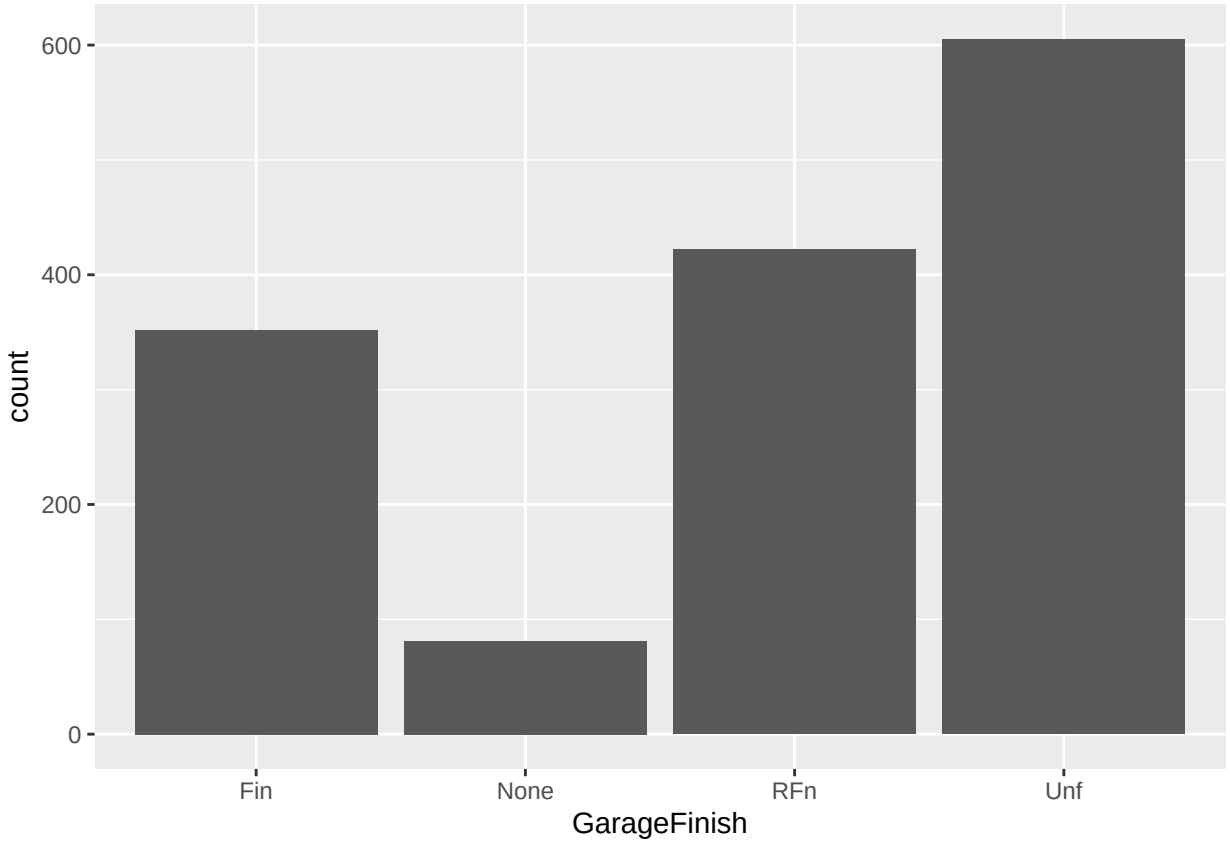
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400
200
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count
Fin
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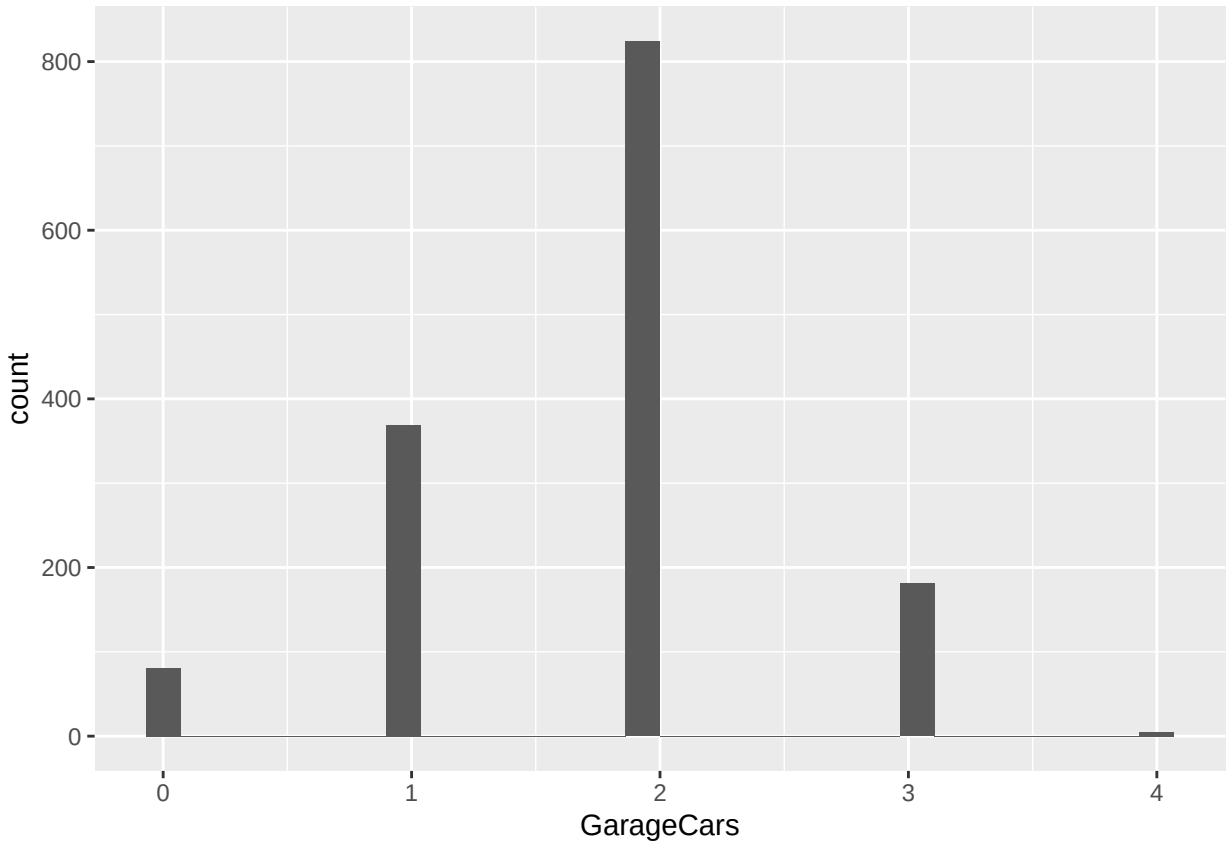
RFn
Unf
GarageFinish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1
2
3
4
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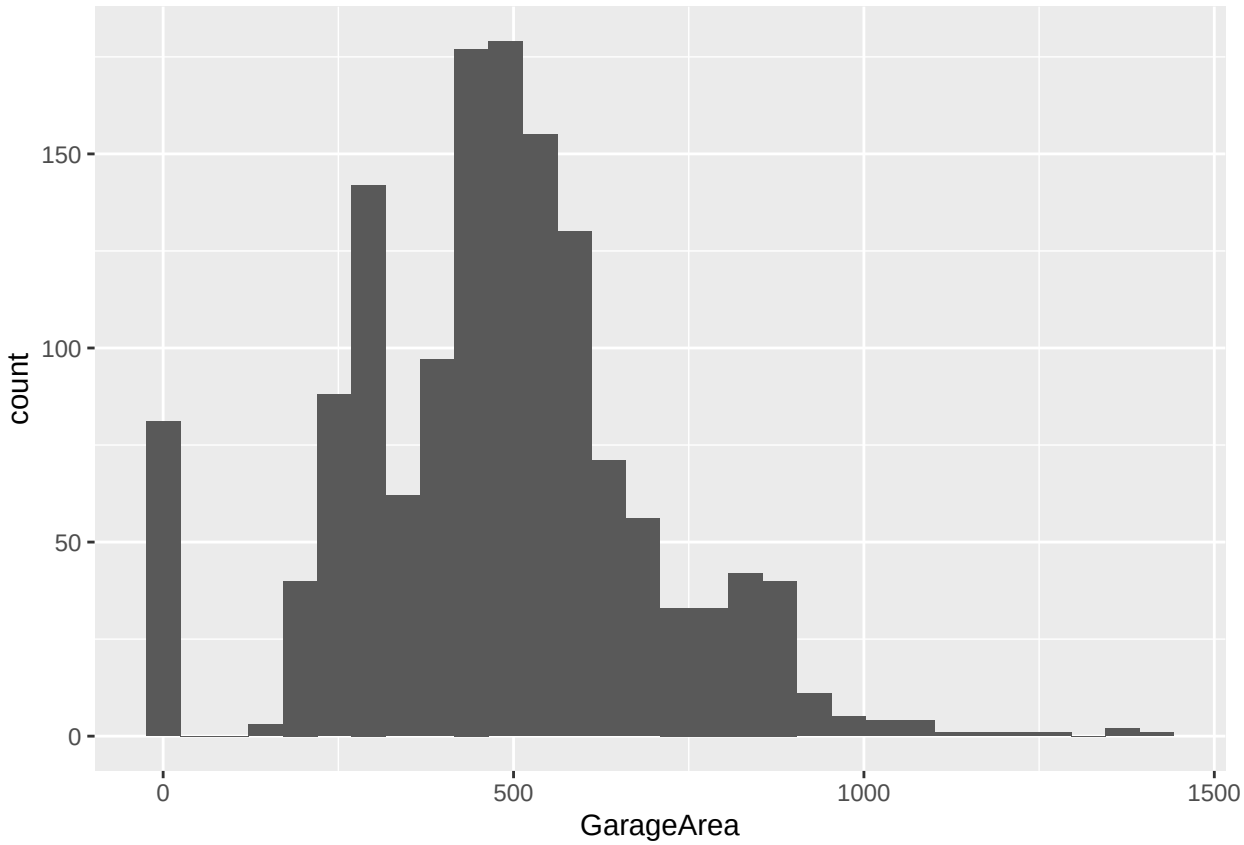
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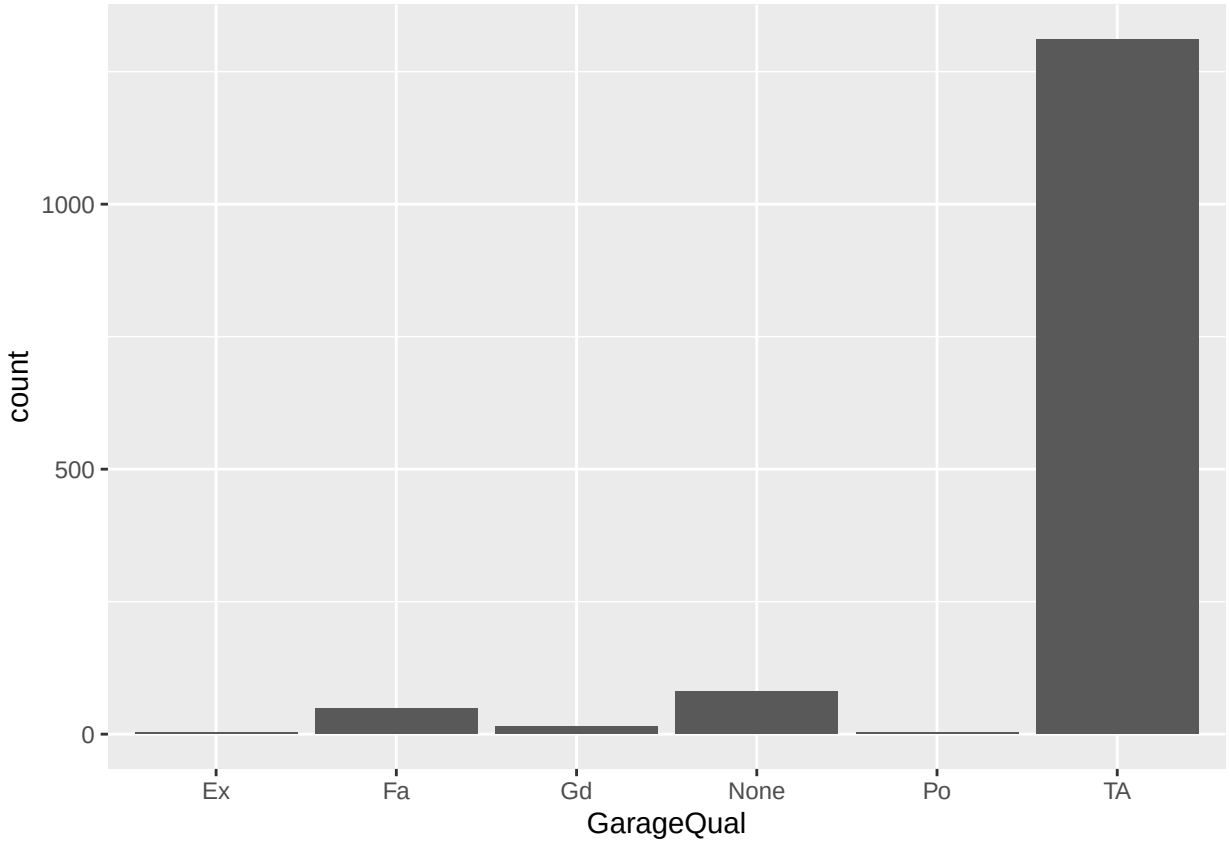
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Gd
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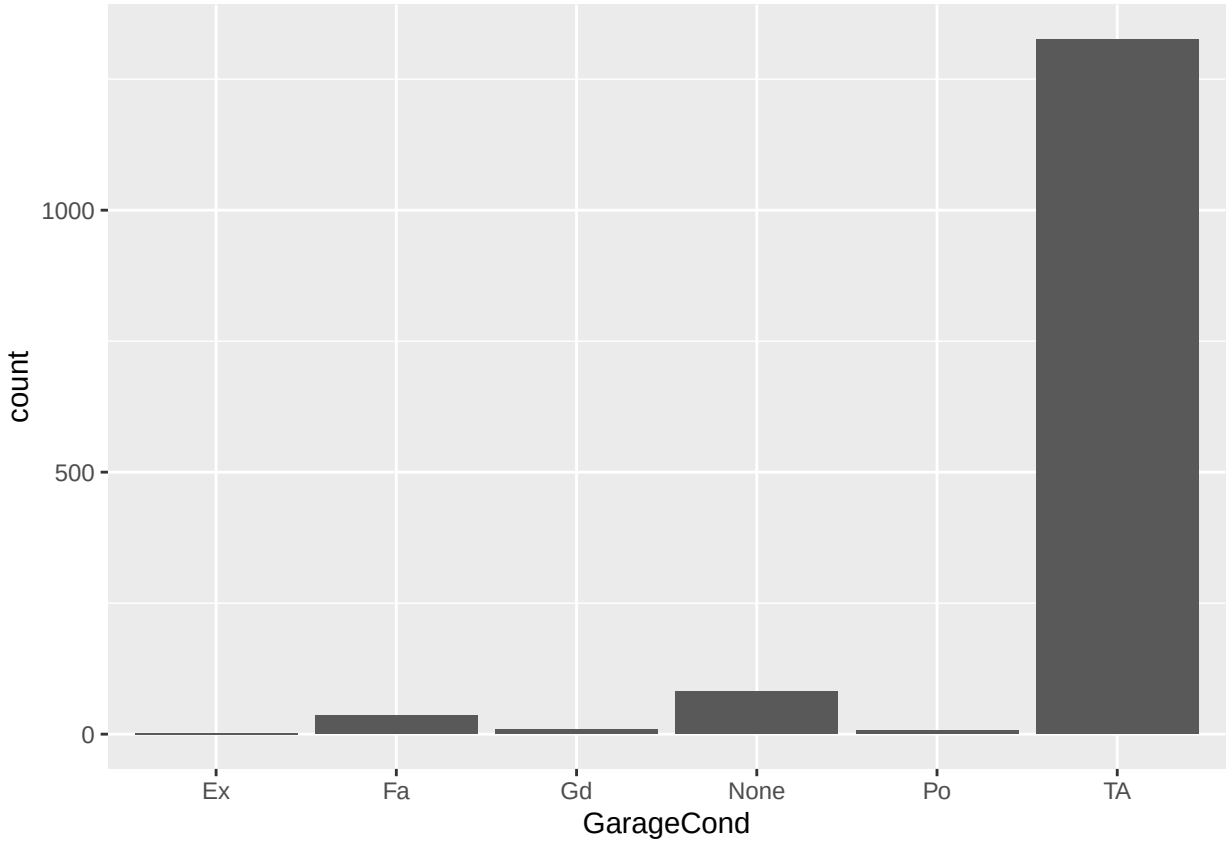
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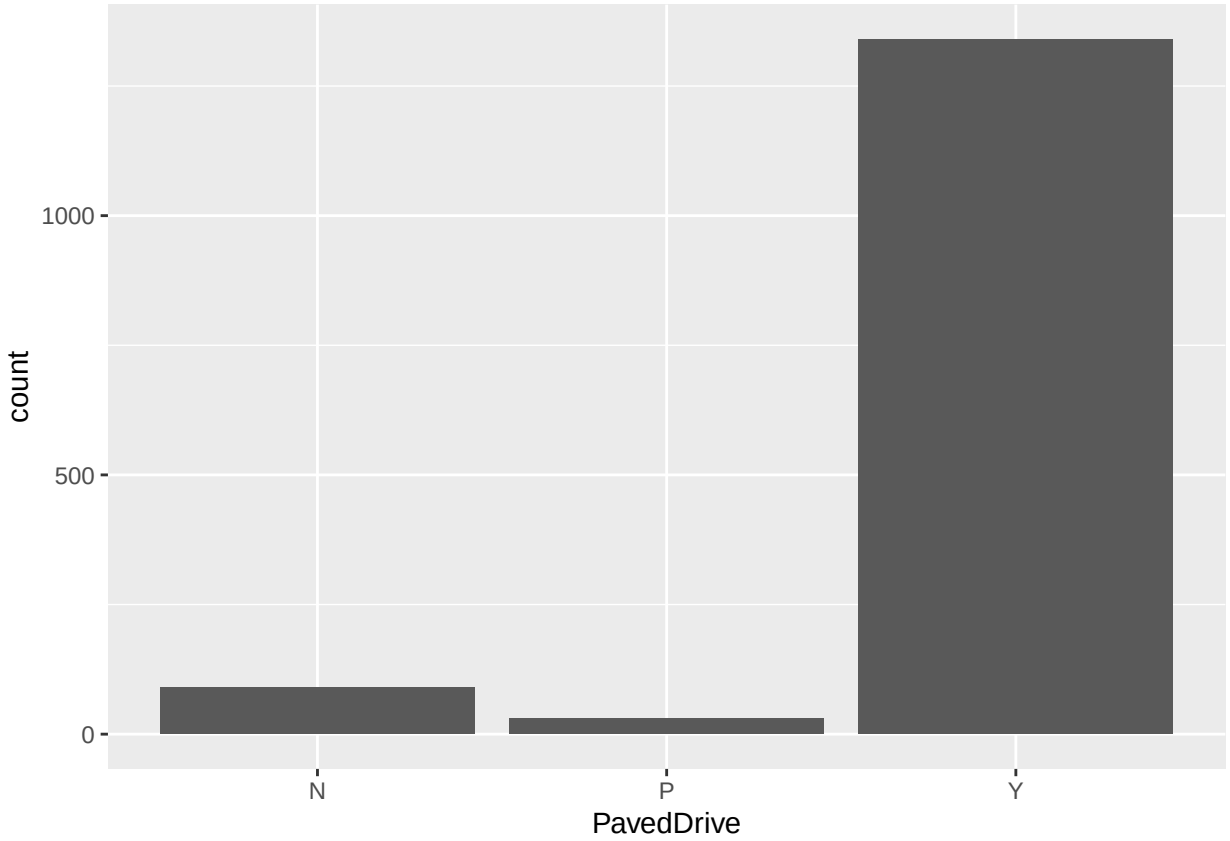
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P
Y
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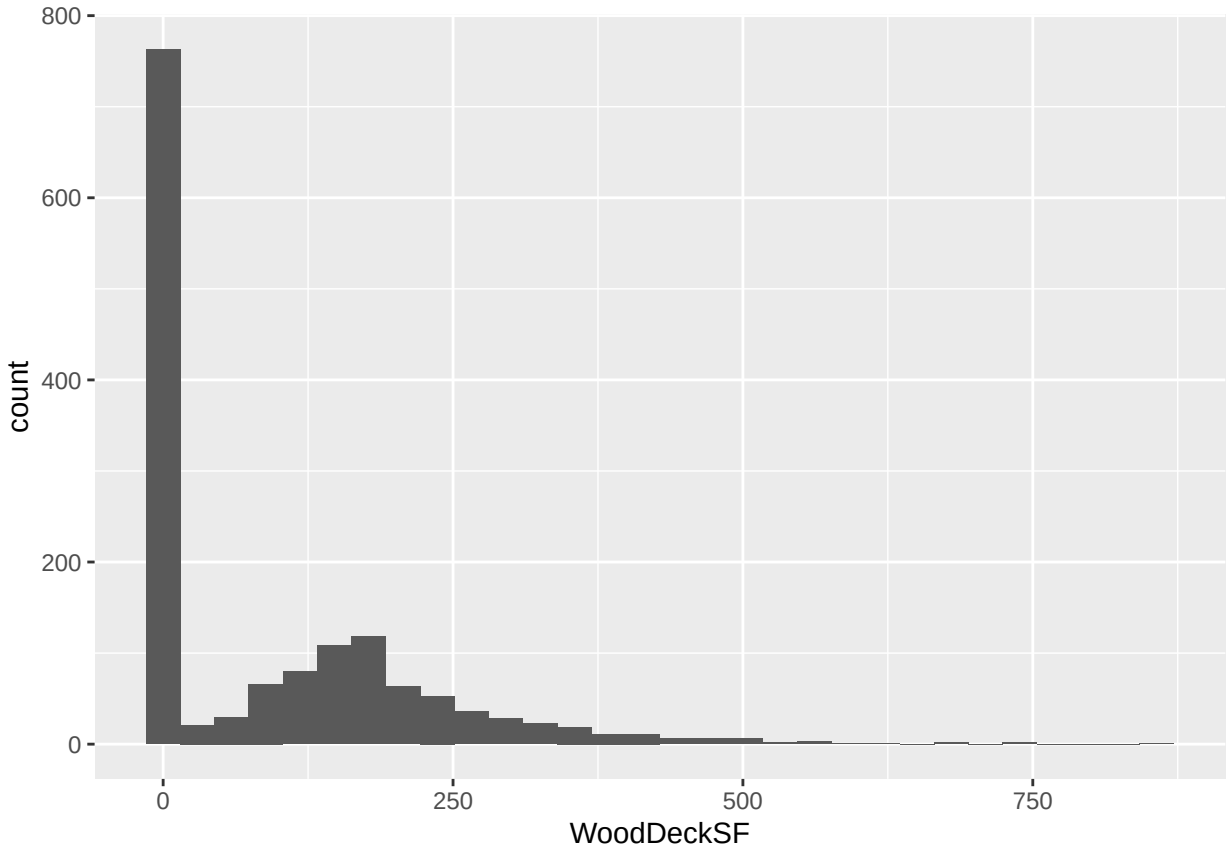
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250
500
750
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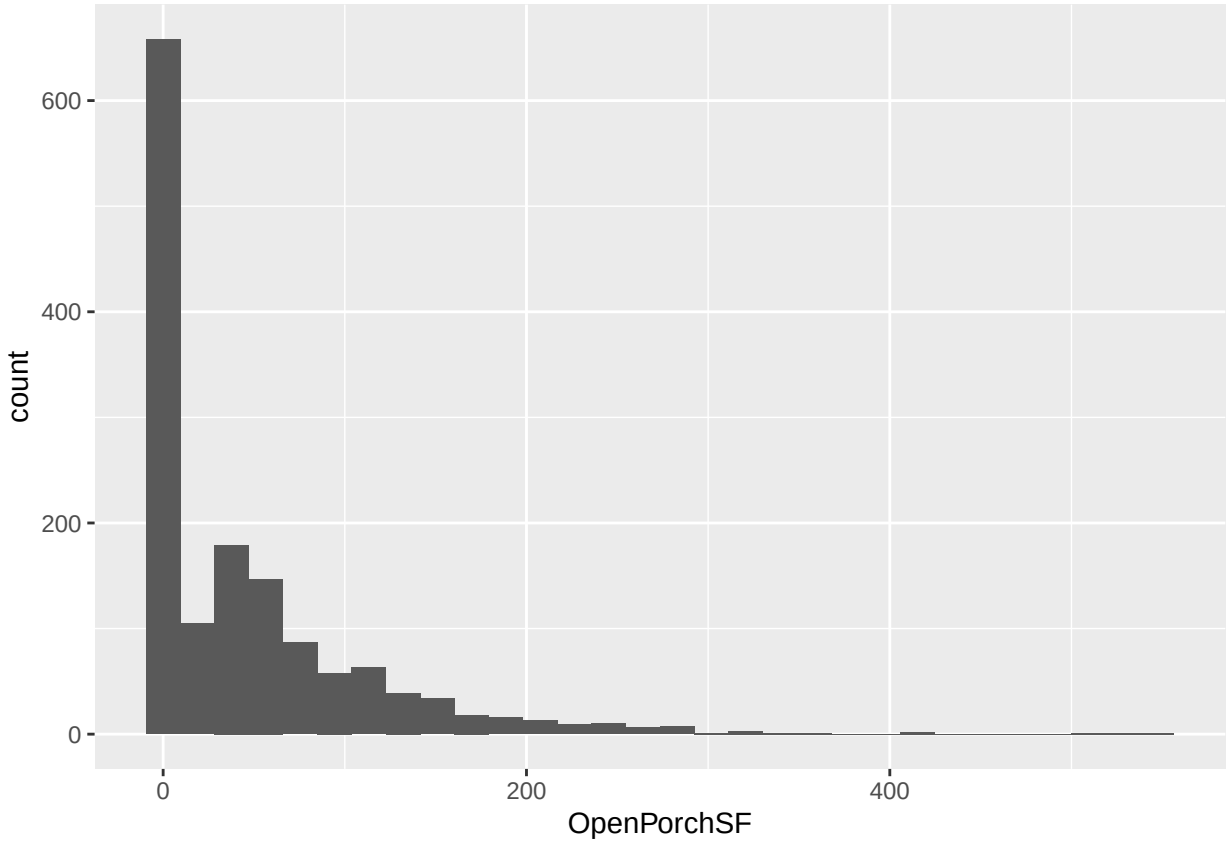
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200
400
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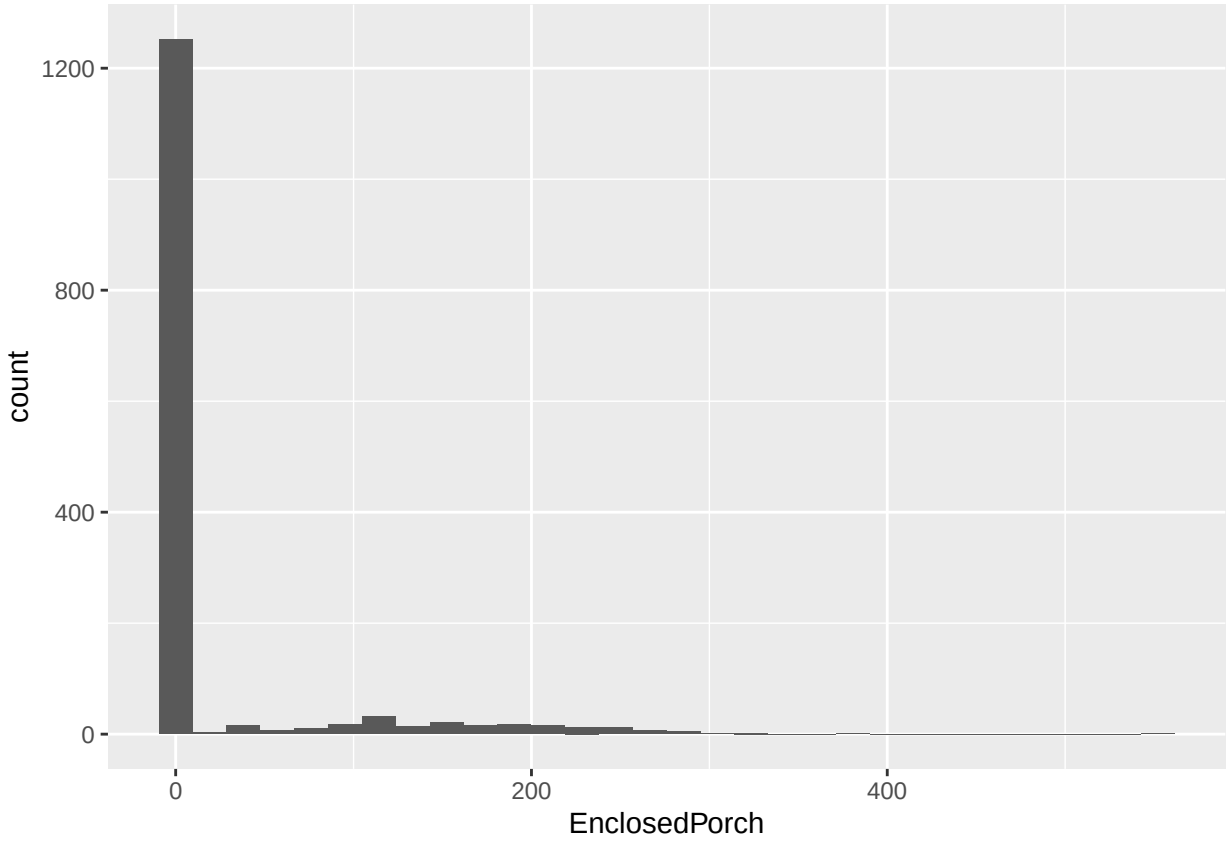
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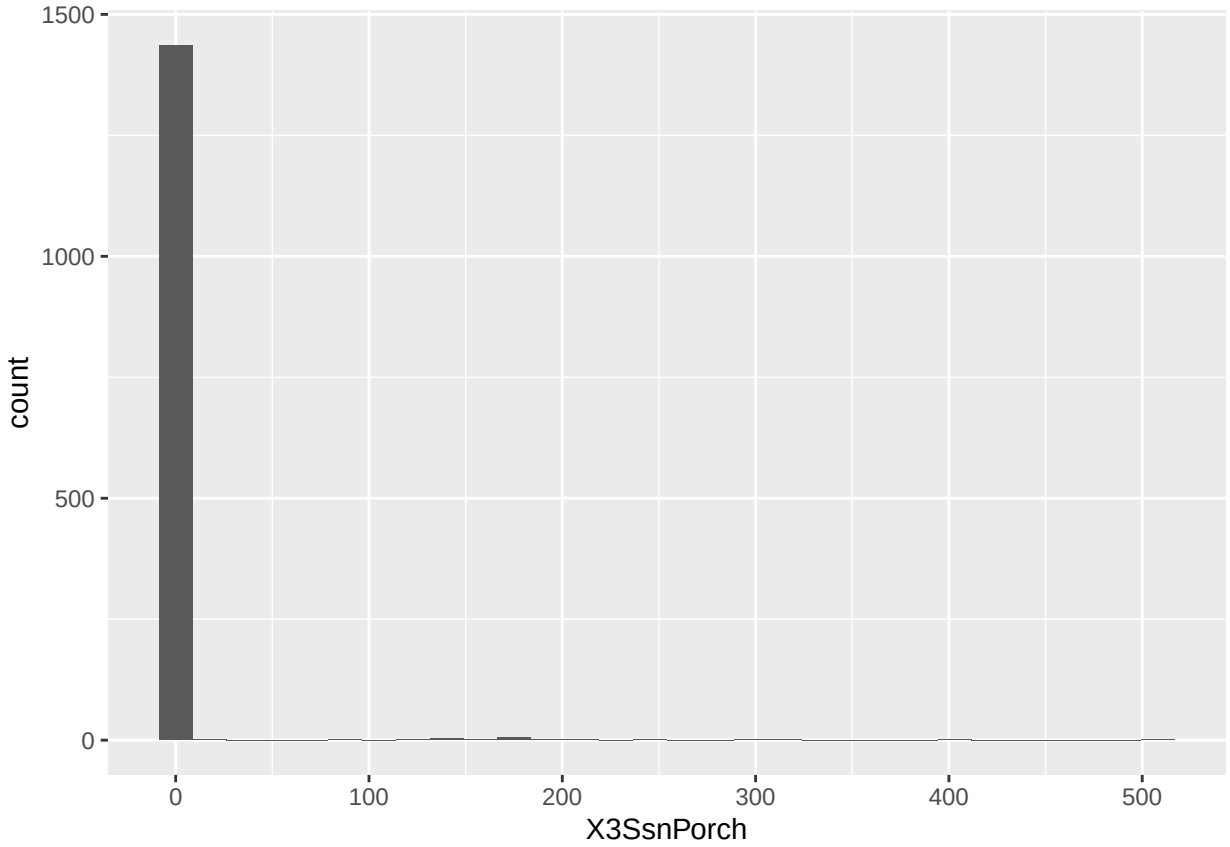
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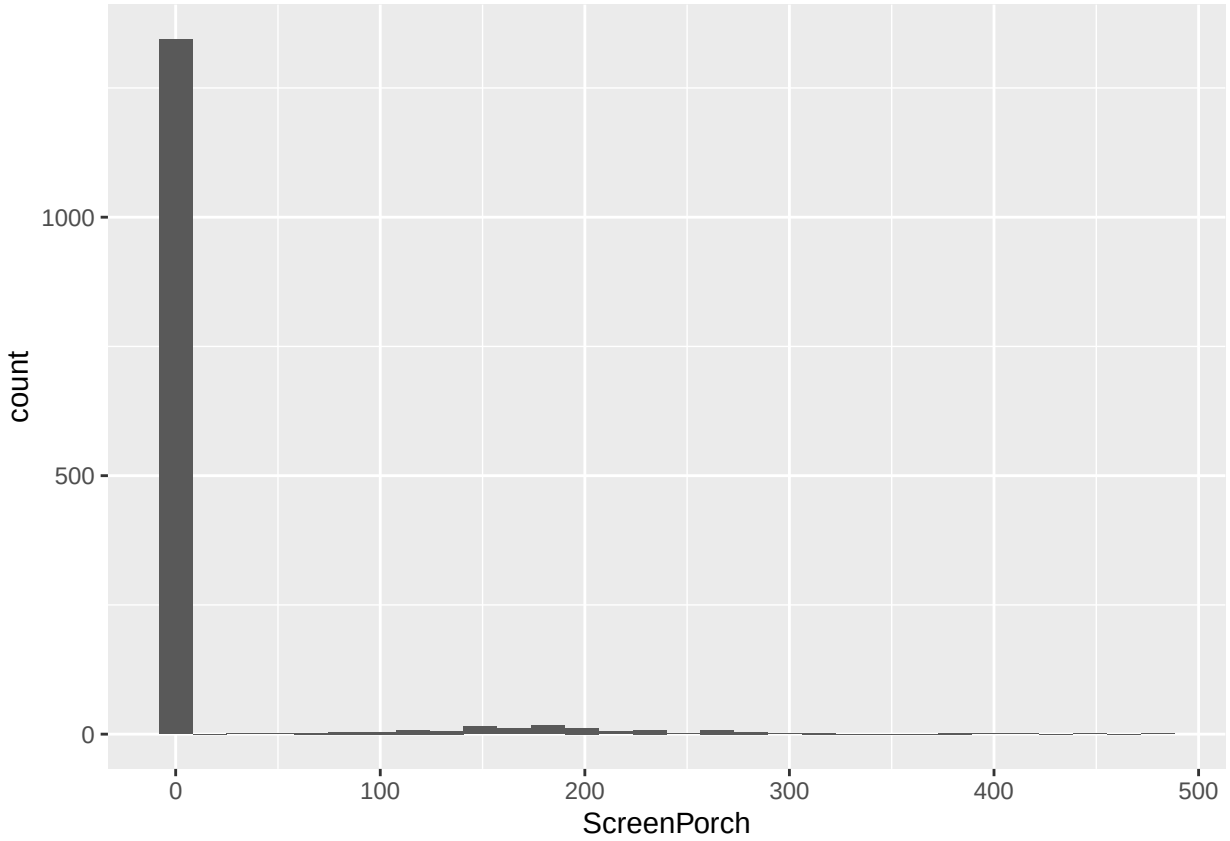
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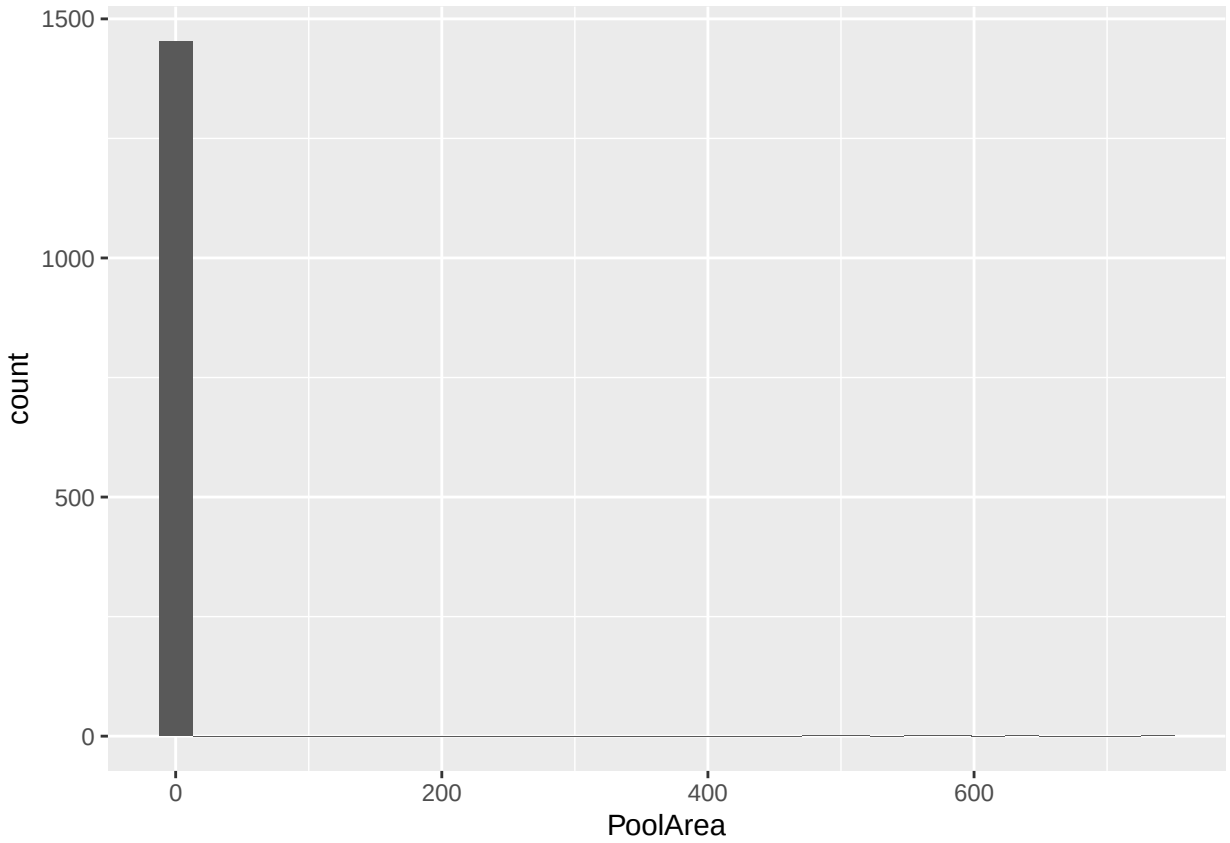
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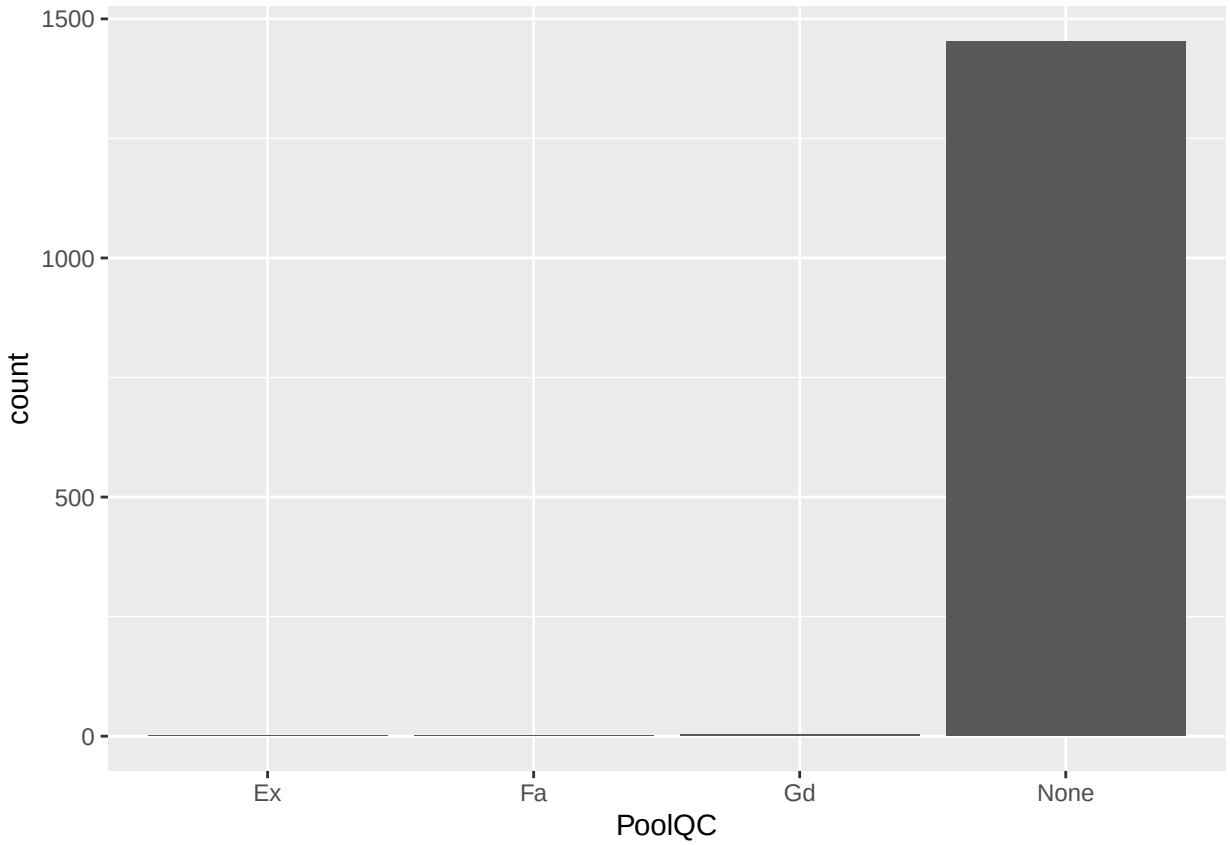
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count
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Fa
Gd
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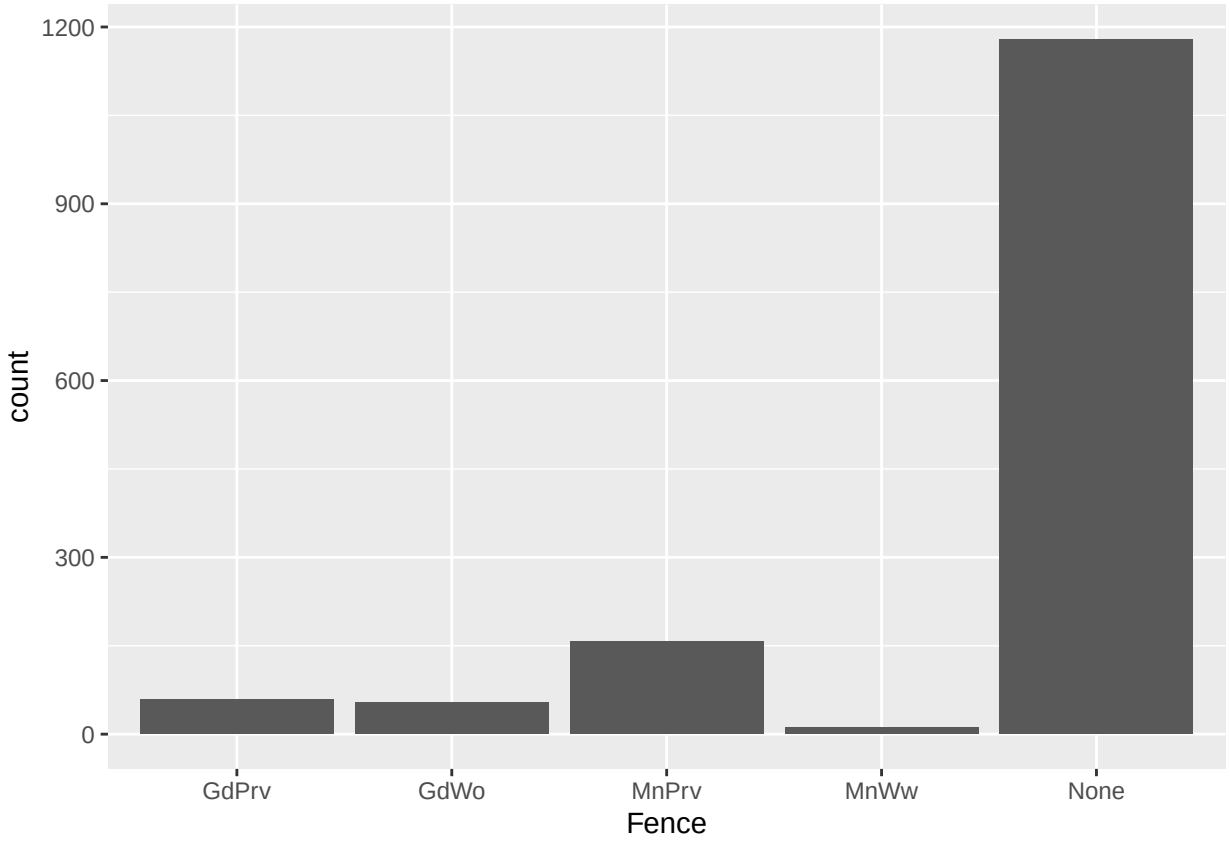
PoolQC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GdWo
MnPrv
MnWw
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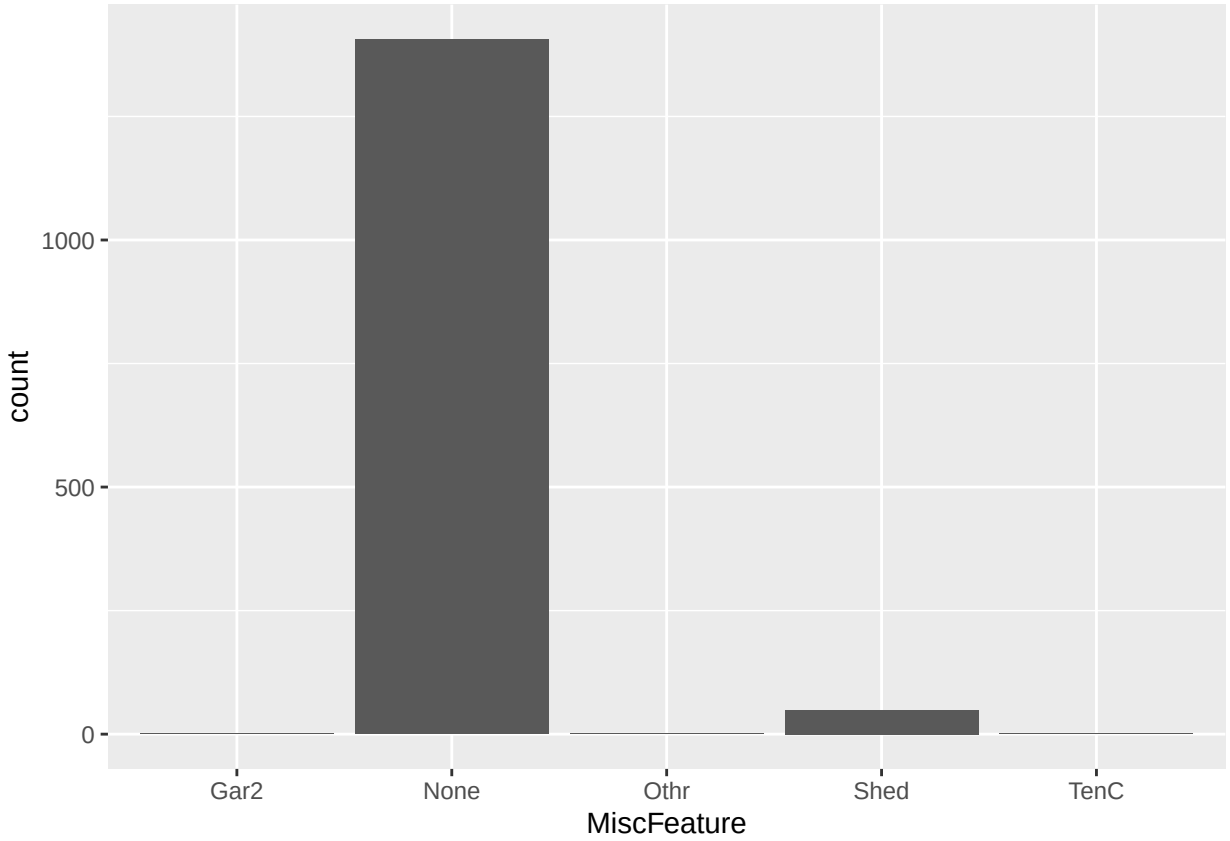
Fence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500
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count
Gar2
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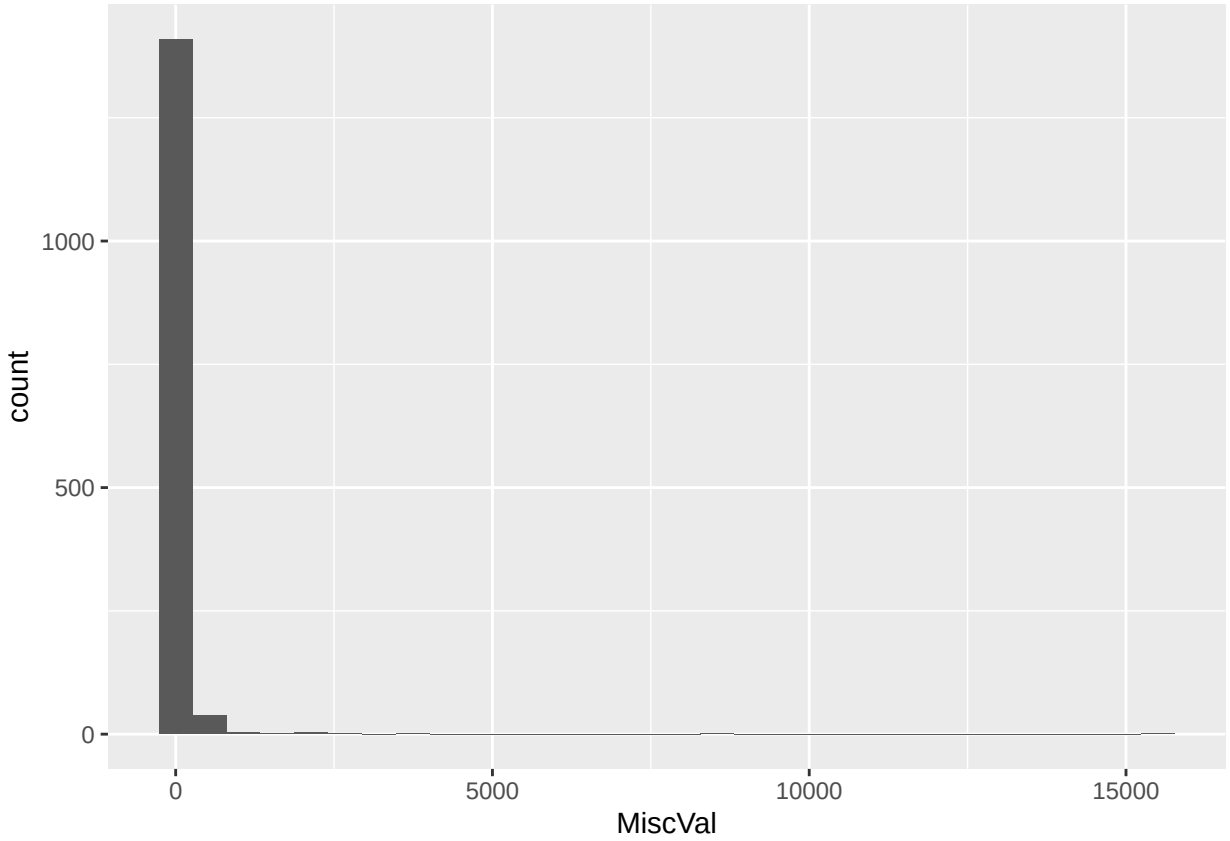
Othr
Shed
TenC
MiscFeature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10000
15000
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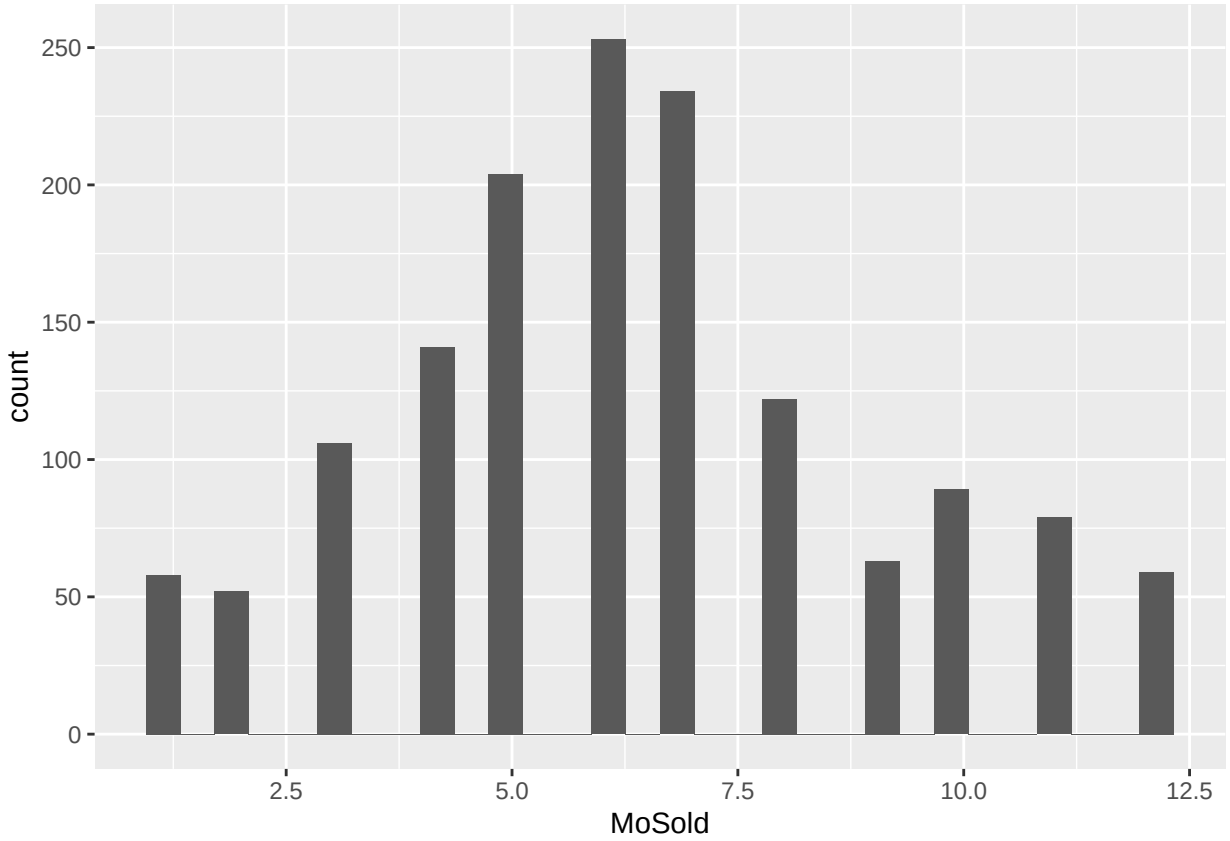
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count
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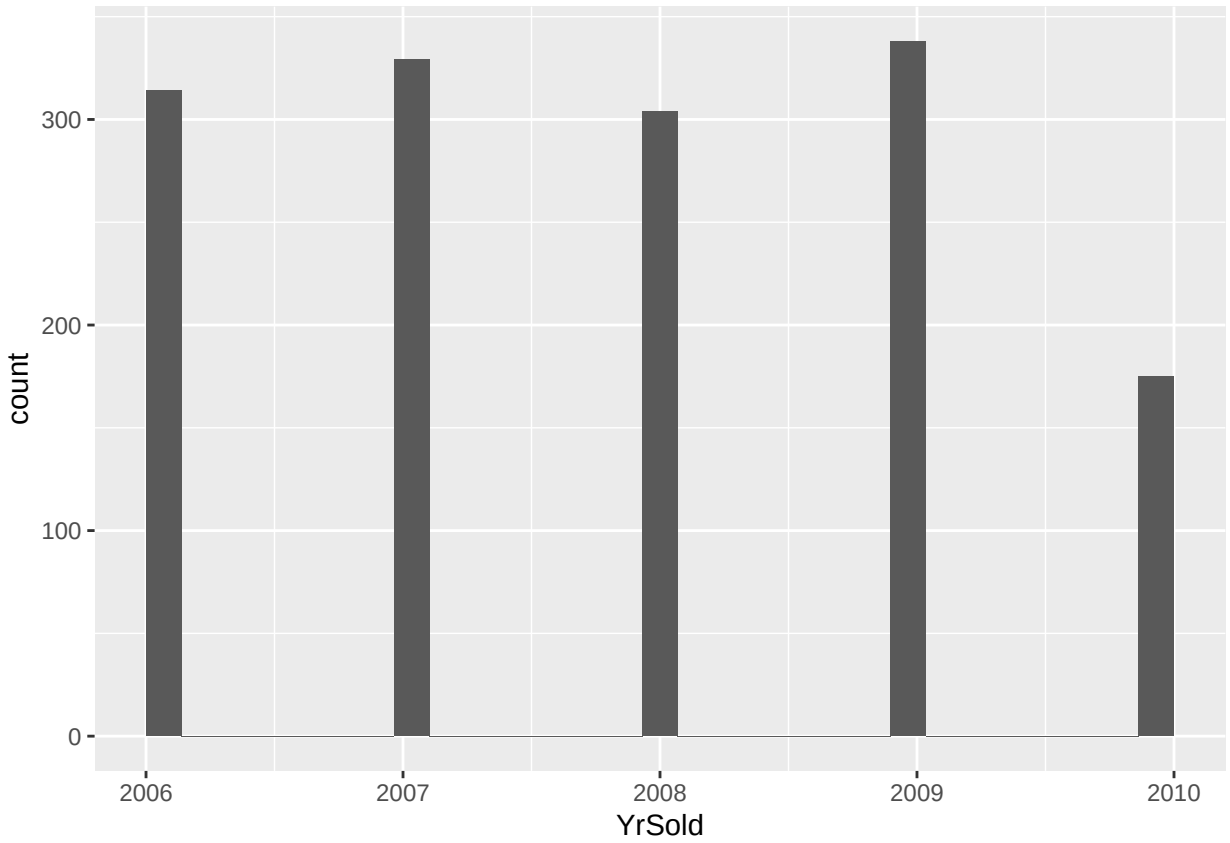
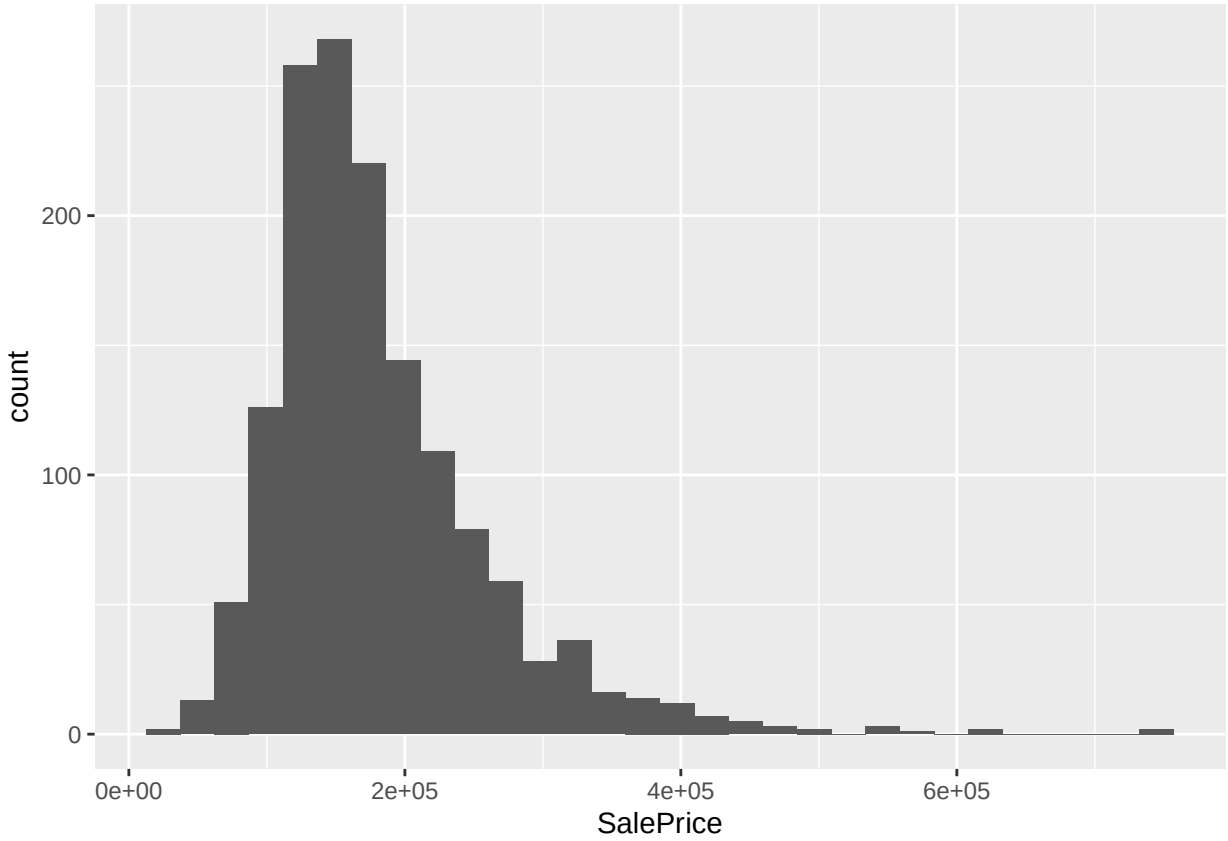
5.0
7.5
10.0
12.5
MoSold


300
200
100
0
count
2006
2007
2008
2009
2010
YrSold



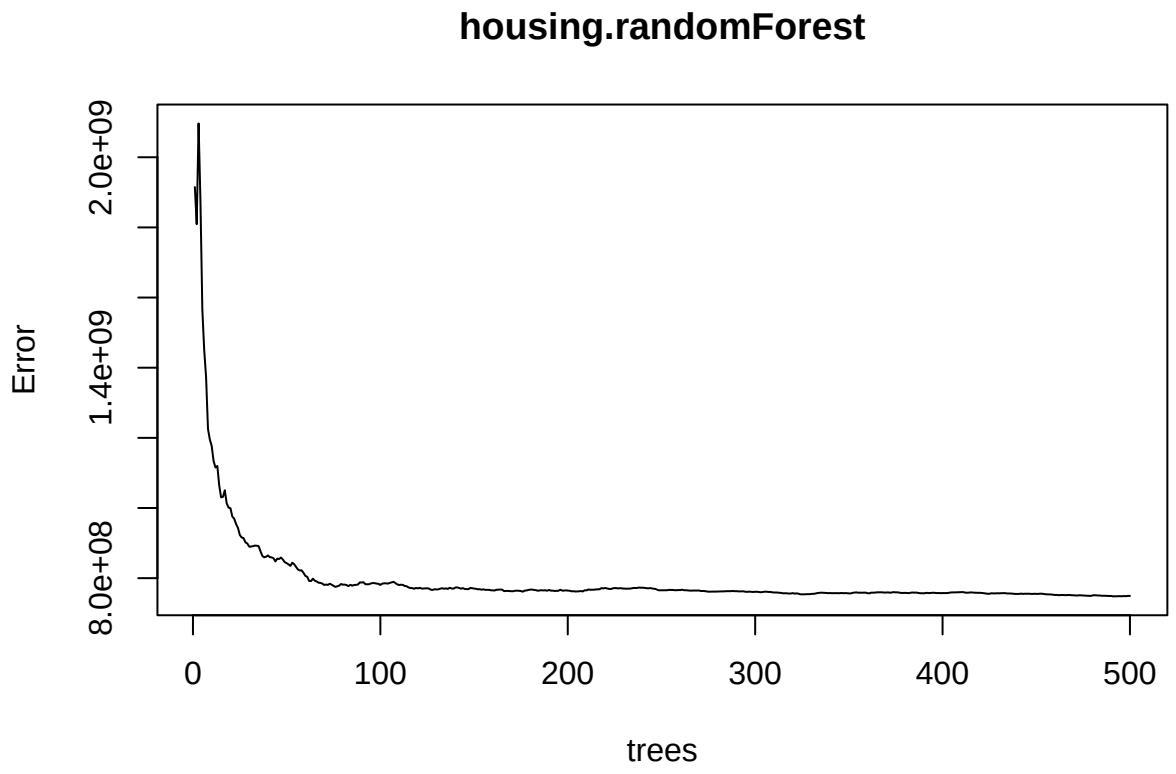
Primary Method - Random Forests

```
set.seed(1234567890)

n <- nrow(dat)

tv.split <- sample(rep(0:1, c(round(n*.3),n-2*round(n*.15))),n)

dat.train <- dat[tv.split==1,]

dat.valid <- dat[tv.split==0,]

housing.randomForest <- randomForest(formula = SalePrice ~ ., data = dat)

housing.randomForest
```

```
##
## Call:
##  randomForest(formula = SalePrice ~ ., data = dat)
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 22
##
```

```
##           Mean of squared residuals: 749248979
##                     % Var explained: 88.12
```

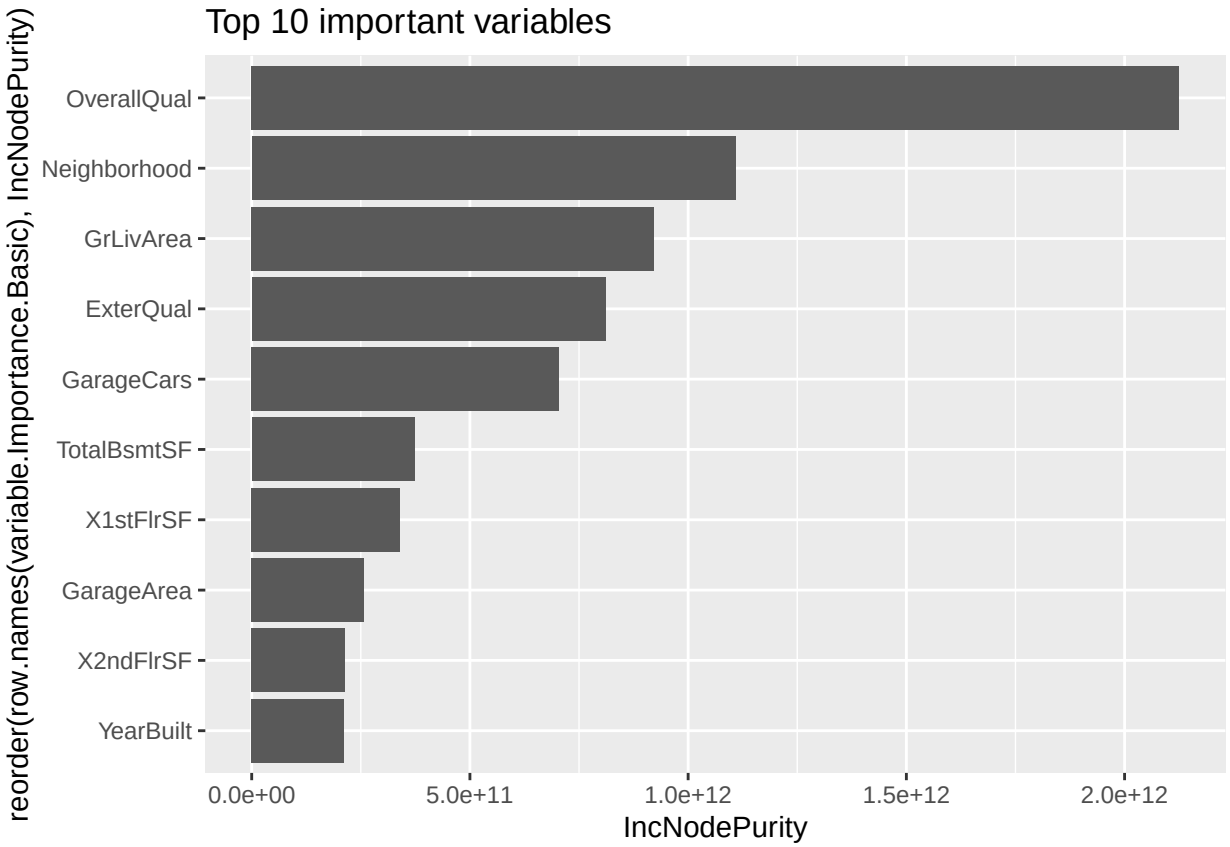
```
plot(housing.randomForest)
```




```
variable.Importance.Basic <- data.frame(housing.randomForest$importance) %>%
  arrange(desc(IncNodePurity)) %>%
  top_n(10)
```

```
## Selecting by IncNodePurity
```

```
(ggplot(data = variable.Importance.Basic,
       aes(x = reorder(row.names(variable.Importance.Basic), IncNodePurity), y = IncNodePurity))
        + geom_col() + coord_flip() + ggtitle("Top 10 important variables"))
```




```
minErrorTreesBasic <- which.min(housing.randomForest$mse)

minErrorTreesBasic
```

```
## [1] 491
```

```
minErrorValueBasic <- sqrt(housing.randomForest$mse[which.min(housing.randomForest$mse)])

minErrorValueBasic
```

```
## [1] 27352.79
```

```
x.valid <- dat.valid[setdiff(names(dat.valid), "SalePrice")]

y.valid <- dat.valid$SalePrice

randomforest.trained <- randomForest(formula = SalePrice ~ ., data = dat.train)

randomforest.trained
```

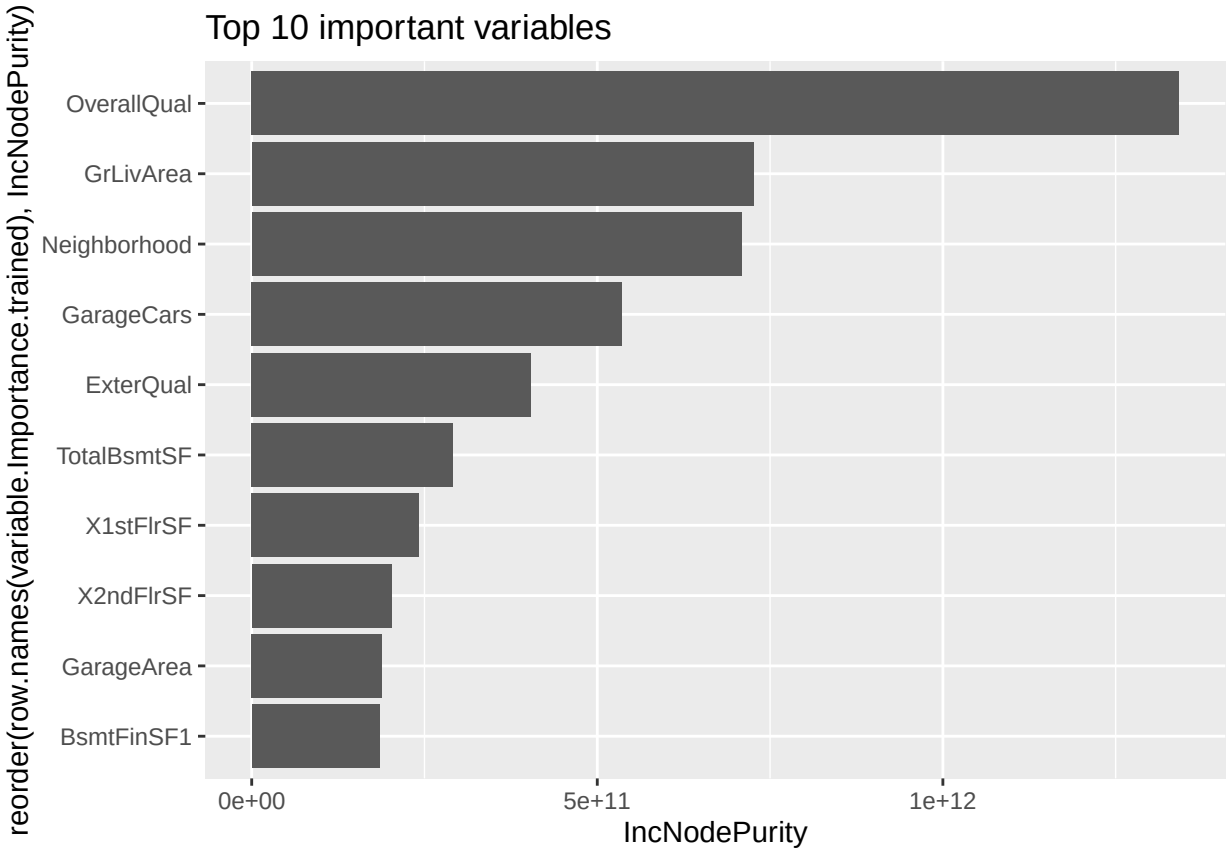
```
##
## Call:
##  randomForest(formula = SalePrice ~ ., data = dat.train)
##                Type of random forest: regression
```

```
##                       Number of trees: 500
## No. of variables tried at each split: 22
##
##           Mean of squared residuals: 964919761
##                     % Var explained: 84.36
```

```
find.RMSPE <- function(true, predicted, df) {
  return(sqrt(sum((predicted - true)^2)/nrow(df)))
}

predictions.valid <- predict(randomforest.trained, dat.valid)

variable.Importance.trained <- data.frame(randomforest.trained$importance) %>%
  arrange(desc(IncNodePurity)) %>%
  top_n(10)
```

```
## Selecting by IncNodePurity
```

```
(ggplot(data = variable.Importance.trained,
       aes(x = reorder(row.names(variable.Importance.trained), IncNodePurity), y = IncNodePurity))
        + geom_col() + coord_flip() + ggtitle("Top 10 important variables"))
```




```
minErrorTreesTrained <- which.min(randomforest.trained$mse)

minErrorTreesTrained
```

```
## [1] 497
```

```
minErrorValueTrained <- sqrt(randomforest.trained$mse[which.min(randomforest.trained$mse)])

minErrorValueTrained
```

```
## [1] 31038.16
```

```
RMSPE <- find.RMSPE(dat.valid$SalePrice, predictions.valid, dat.valid)

RMSPE
```

```
## [1] 25529.17
```

```
randomforest.validated <- randomForest(formula = SalePrice ~ ., data = dat.train,
                                       xtest = x.valid, ytest = y.valid)

randomforest.validated
```

```
##
## Call:
##  randomForest(formula = SalePrice ~ ., data = dat.train, xtest = x.valid,      ytest = y.valid)
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 22
##
##           Mean of squared residuals: 952389999
##                     % Var explained: 84.56
##                        Test set MSE: 660213523
##                     % Var explained: 90.04
```

```
minErrorTreesOOB <- which.min(randomforest.validated$mse)

minErrorTreesOOB
```

```
## [1] 436
```

```
minErrorValueOOB <- sqrt(randomforest.validated$mse[which.min(randomforest.validated$mse)])

minErrorValueOOB
```

```
## [1] 30792.35
```

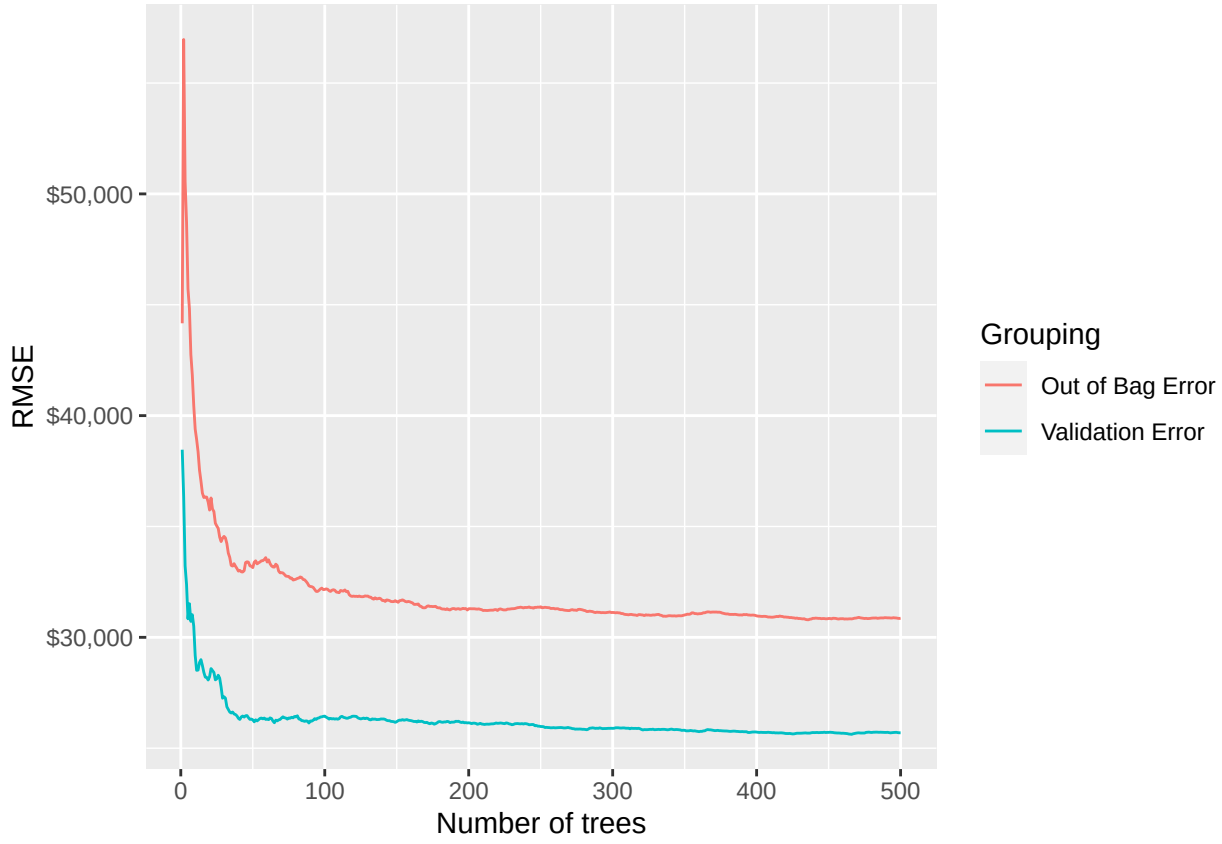
```
minErrorTreesValidation <- which.min(randomforest.validated$test$mse)

minErrorTreesValidation
```

```
## [1] 466
```

```
minErrorValueValidation <- sqrt(randomforest.validated$test$mse[which.min(randomforest.validated$test$ms

minErrorValueValidation
```

```
## [1] 25625.55
```

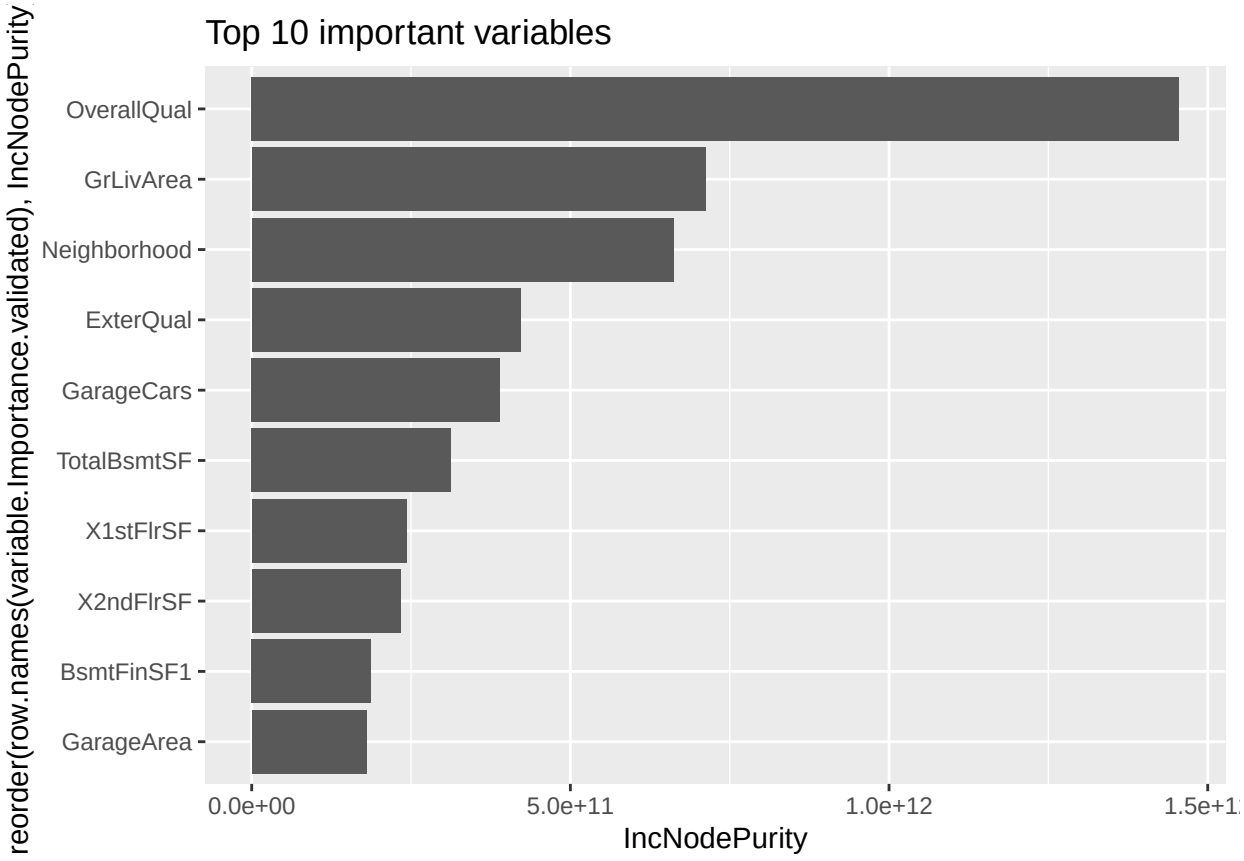
```
tibble(`Out of Bag Error` = sqrt(randomforest.validated$mse),
       `Validation Error` = sqrt(randomforest.validated$test$mse),
       ntrees = 1:randomforest.validated$ntree) %>%
  gather(Grouping, RMSE, -ntrees) %>%
  ggplot(aes(ntrees, RMSE, color = Grouping)) +
  geom_line() +
  scale_y_continuous(labels = scales::dollar) +
  xlab("Number of trees")
```




```
variable.Importance.validated <- data.frame(randomforest.validated$importance) %>%
  arrange(desc(IncNodePurity)) %>%
  top_n(10)
```

```
## Selecting by IncNodePurity
```

```
(ggplot(data = variable.Importance.validated,
       aes(x = reorder(row.names(variable.Importance.validated), IncNodePurity), y = IncNodePurity))
        + geom_col() + coord_flip() + ggtitle("Top 10 important variables"))
```


Top 10 important variables
reorder(row.names(variable.Importance.validated), IncNodePurity)
OverallQual
GrLivArea
Neighborhood
ExterQual
GarageCars
TotalBsmtSF
X1stFlrSF
X2ndFlrSF
BsmtFinSF1
GarageArea
0.0e+00
5.0e+11
1.0e+12
IncNodePurity